Class III Injection Wells

Valois Robinson ⅄ Region 8 UIC Program
(303) 312-6276 ⅄ robinson.valois@epa.gov

Two poll questions:
Do you work for EPA or a State Primacy Program? ☐ State Primacy Program ☐ EPA
Have you visited or worked for a Class III facility? ☐ Yes ☐ No

What are Class III Injection Wells?

40 CFR § 144.6 Classification of wells

(c) *Class III.* Wells which inject for extraction of minerals including:

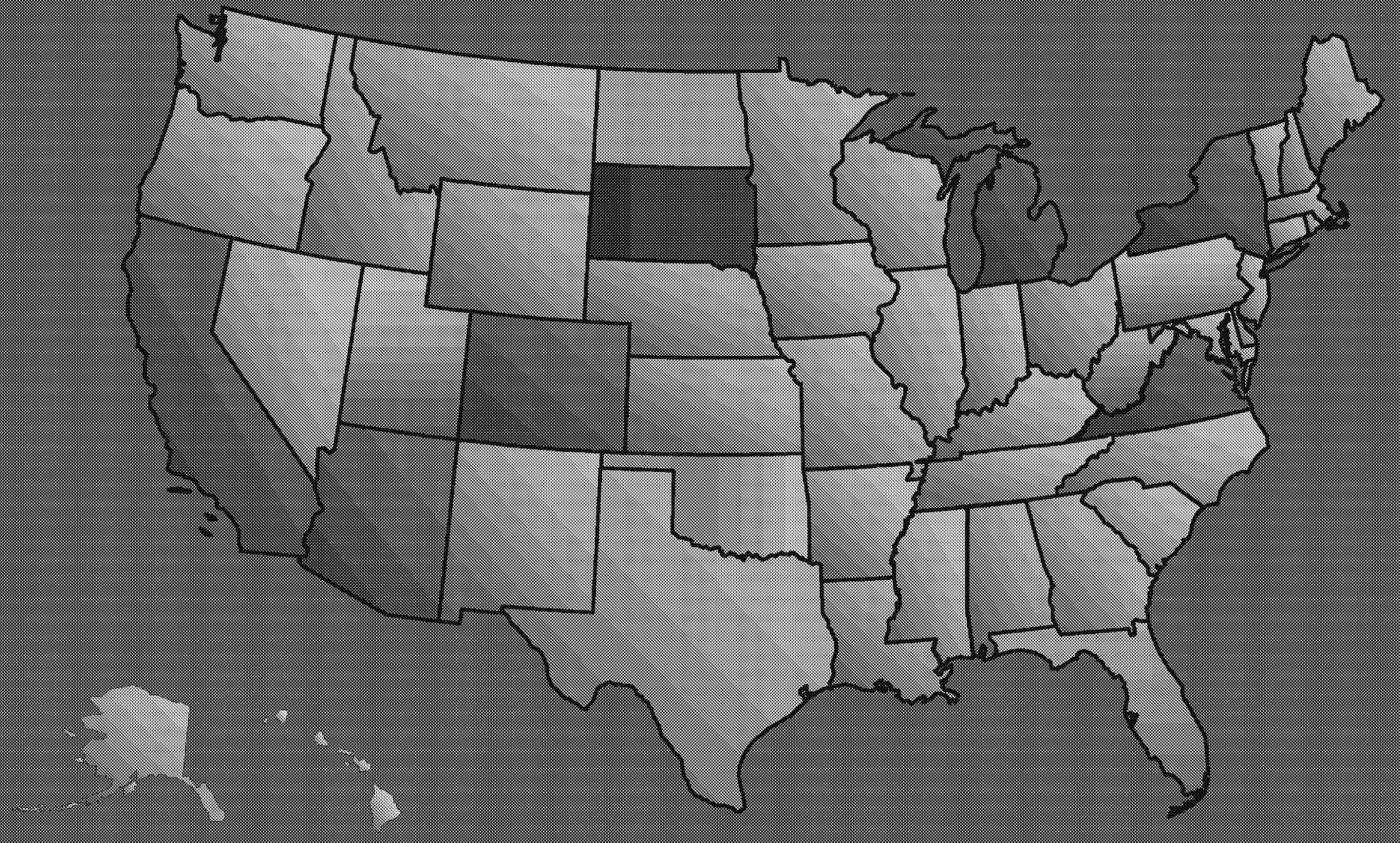
(1) Mining of sulfur by the Frasch process;

(2) In situ production of uranium or other metals; this category includes only in-situ production from ore bodies which have not been conventionally mined.

(Solution mining of conventional mines such as stope leaching is included in Class V.)

(3) Solution mining of salts or potash.

States With Class III Injection Wells

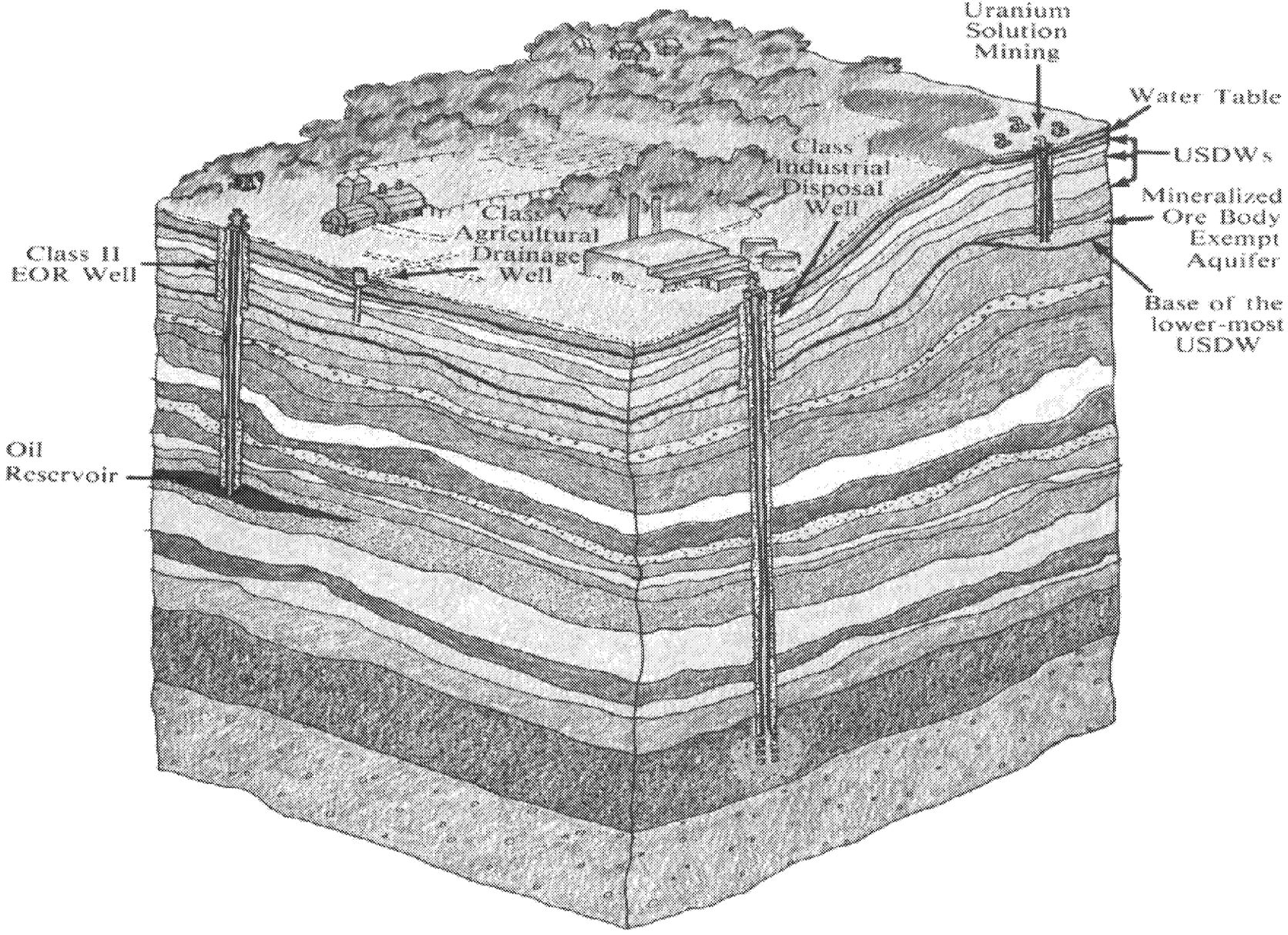


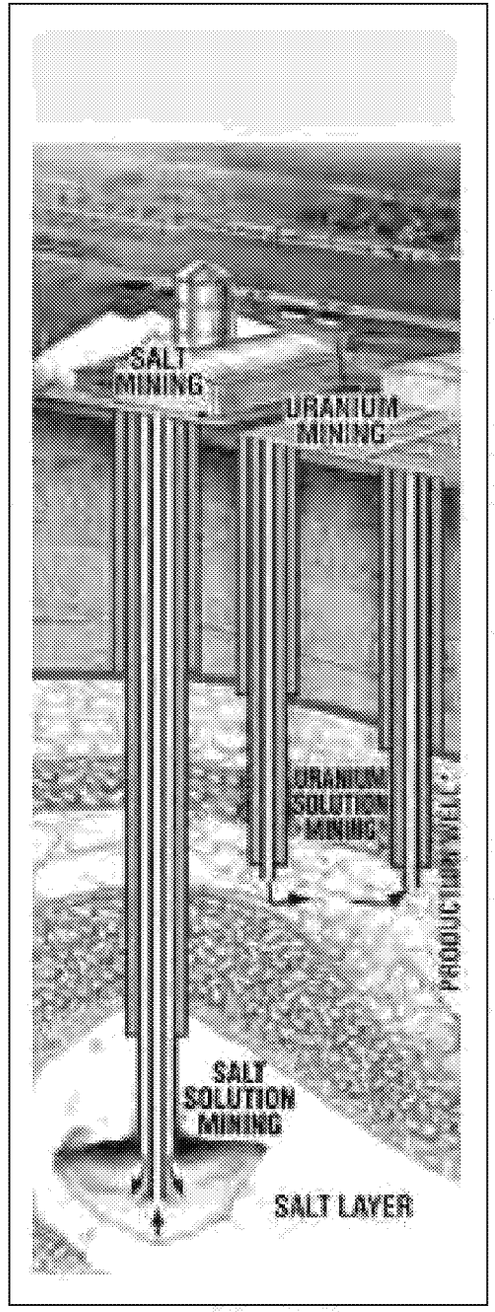
Primacy States with Class III Injection Wells

Direct Implementation States with Class III Injection Wells

States with no Class III Injection Wells

Injection Well Relationship to USDWs





40 CFR Part 146
Subpart D—Criteria and Standards Applicable to Class III Wells

What are Class III Injection Wells?

40 CFR §144.6 Classification of wells

(c) *Class III.* Wells which inject for extraction of minerals including:

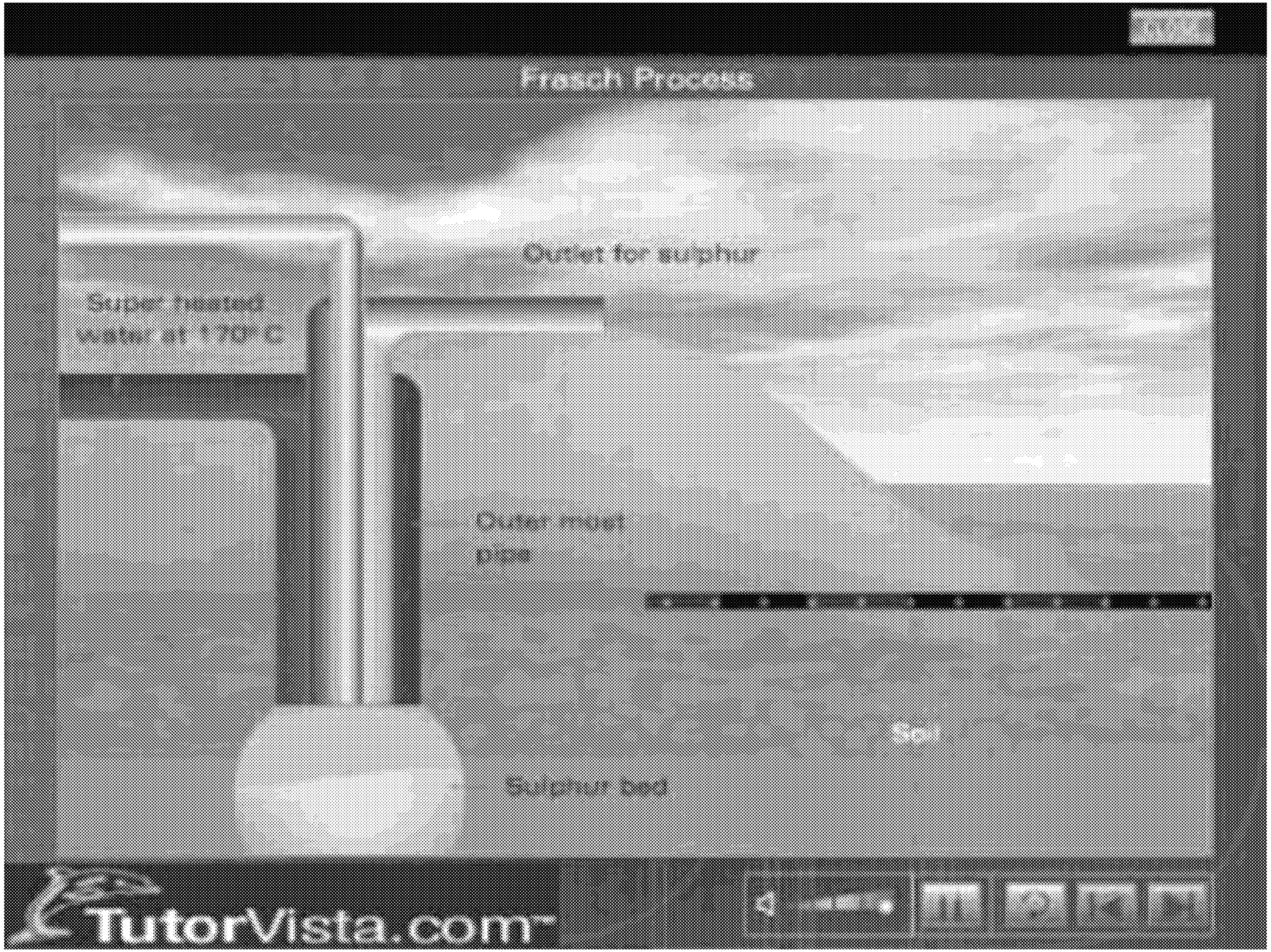
(1) Mining of sulfur by the Frasch process;

- Prior to 2000, mining operations in the Gulf of Mexico region recovered sulfur by this solution mining method.

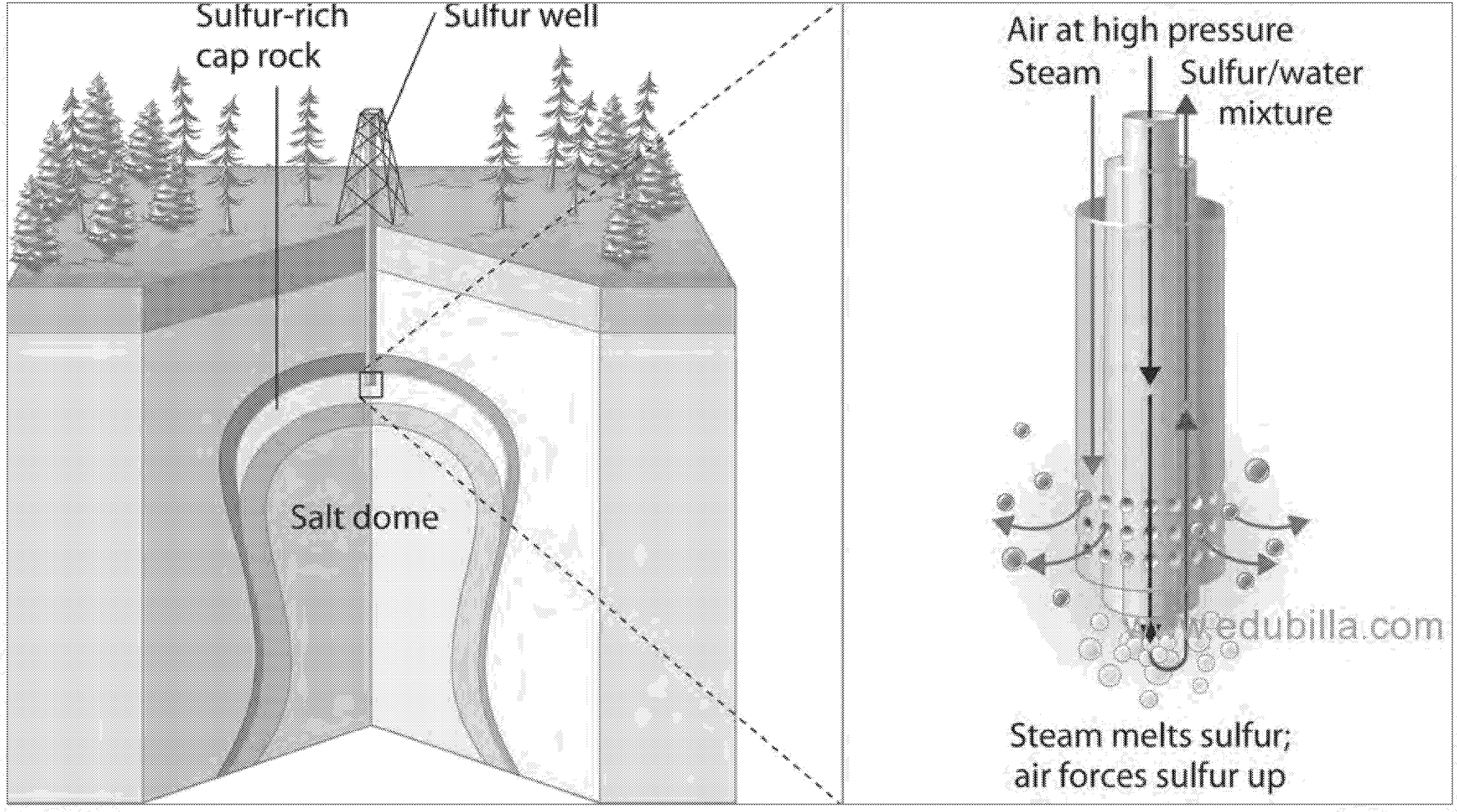
(2) In situ production of uranium or other metals;

(3) Solution mining of salts or potash.

Play Video: FraschProcessSulphur.mp4



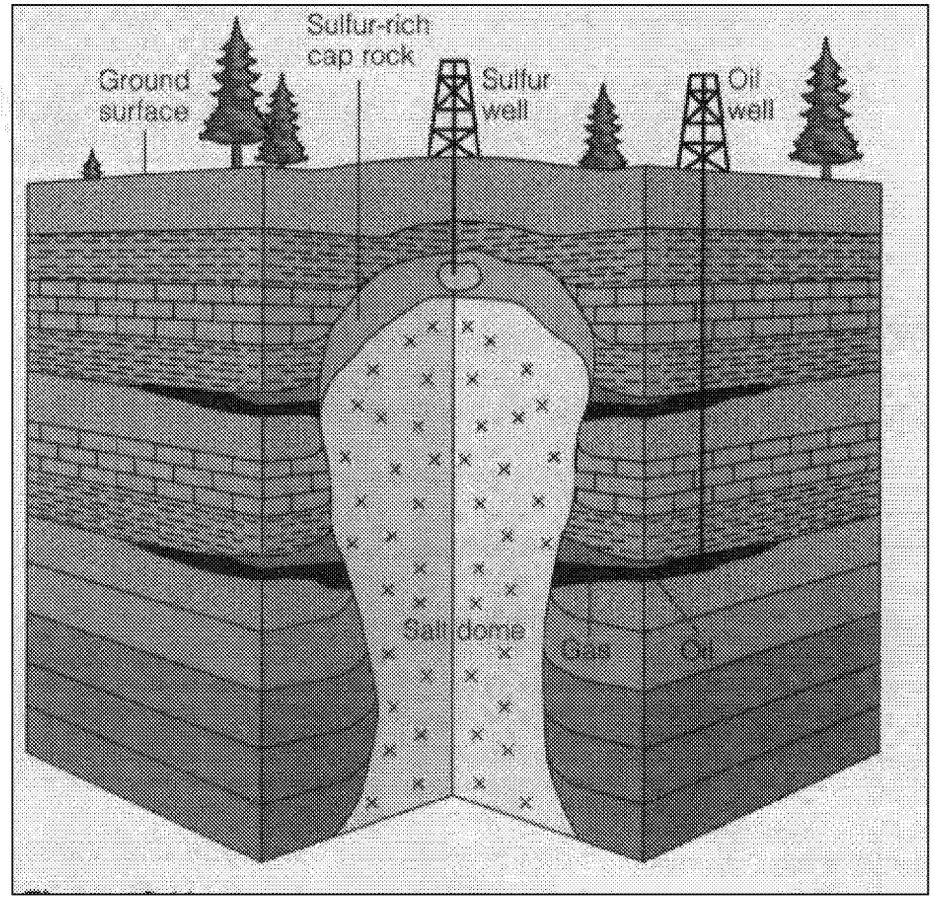
Frasch Process for Sulfur Recovery



How does sulfur form as cap on a salt dome?

Bacteria feed on a hydrocarbon like methane and cause certain chemical reactions to occur which in simplified form look like this:

$CaSO_4$ (anhydrite) + CH_4 (methane or other hydrocarbons) = H_2S (hydrogen sulfide) + $CaCO_3$ + H_2O



Waste product of the bacterial metabolism hydrogen sulfide will react with oxygen to form elemental sulfur:

$2H_2S + O_2 = 2S + 2H_2O$

What are Class III Injection Wells?

40 CFR §144.6 Classification of wells

(c) *Class III.* Wells which inject for extraction of minerals including:

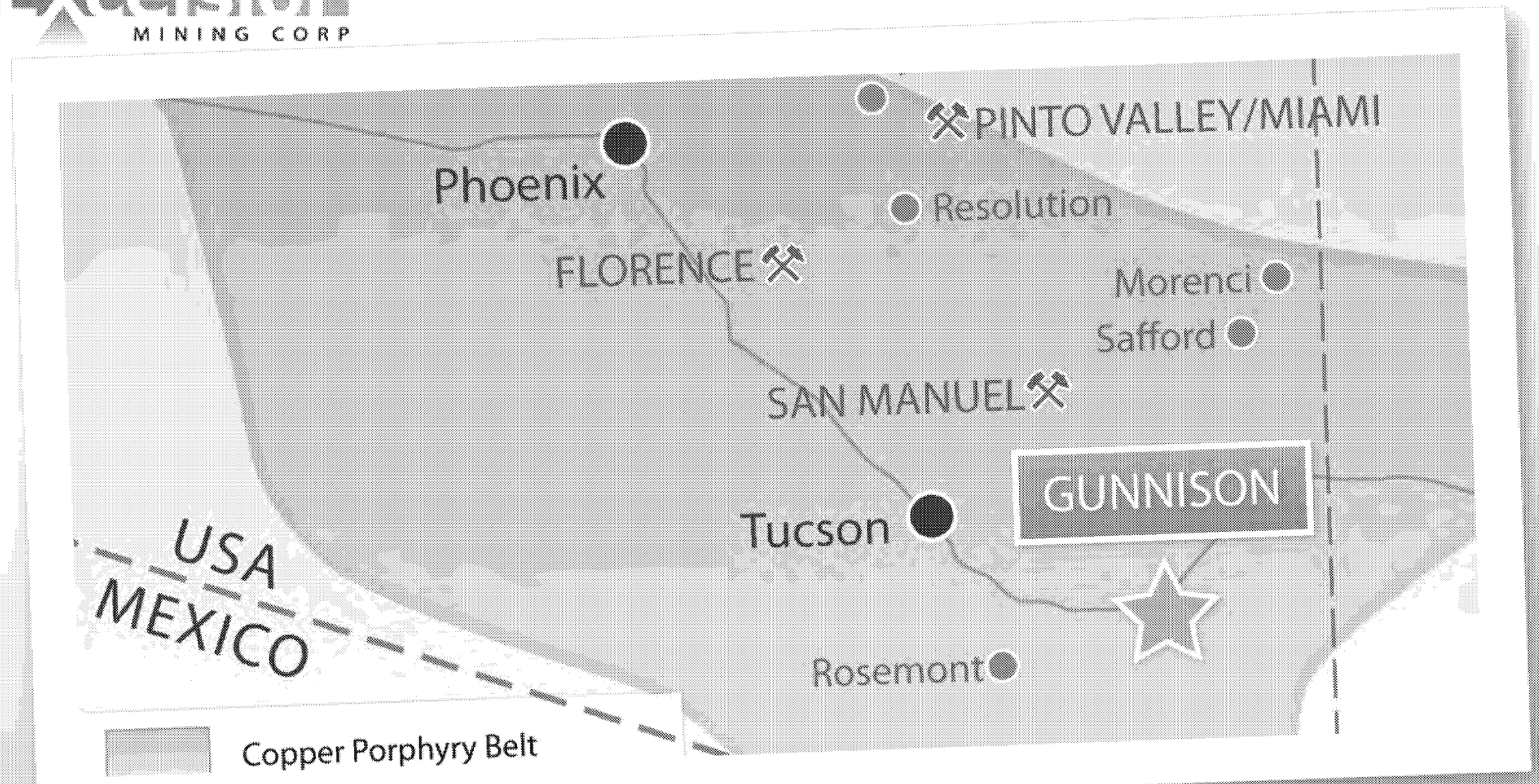
(1) Mining of sulfur by the Frasch process;

(2) In situ production of uranium or other metals;

- Excelsior Gunnison Copper
- Florence Copper
- Uranium ISR project

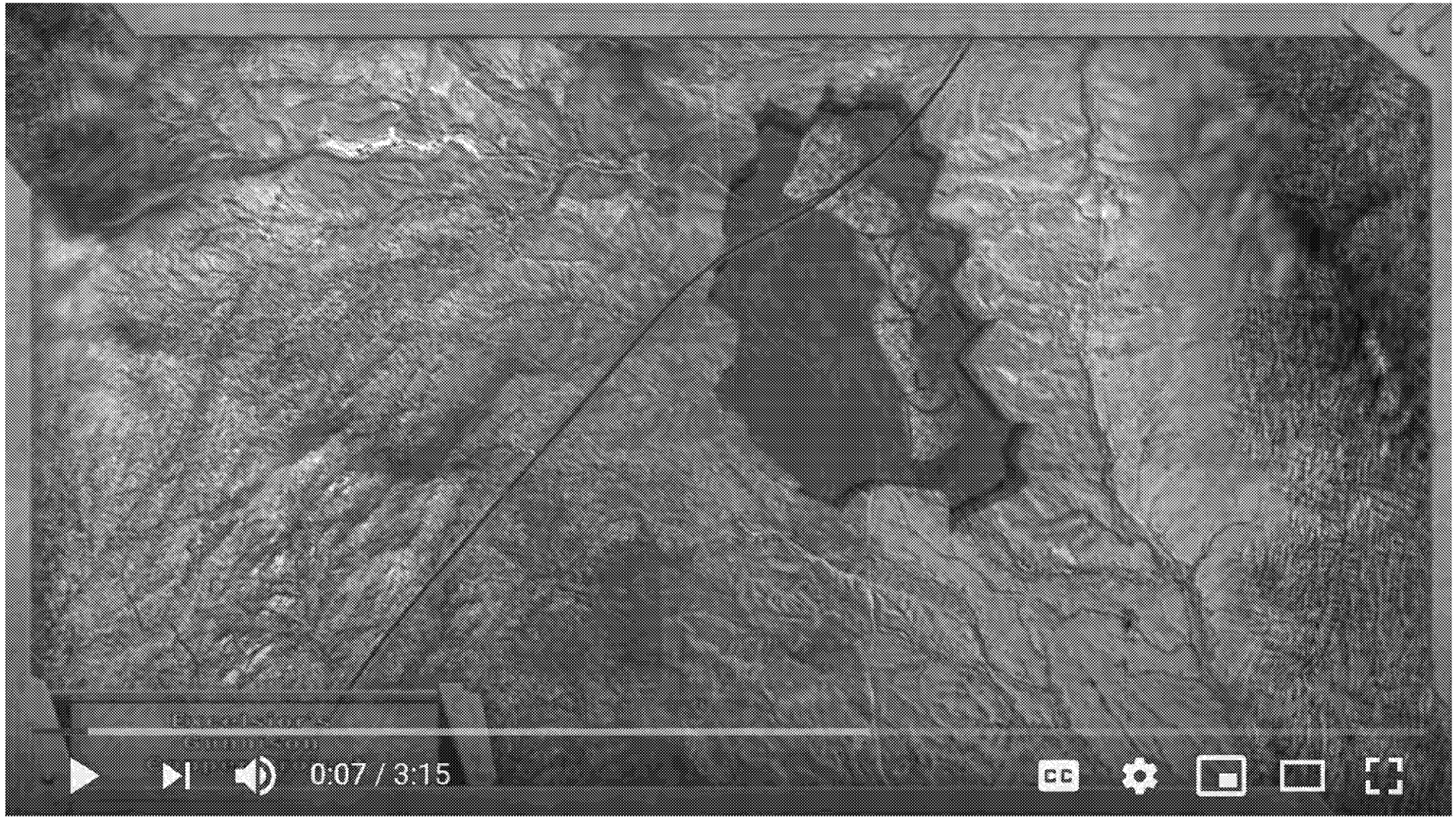
(3) Solution mining of salts or potash.

Excelsior
MINING CORP

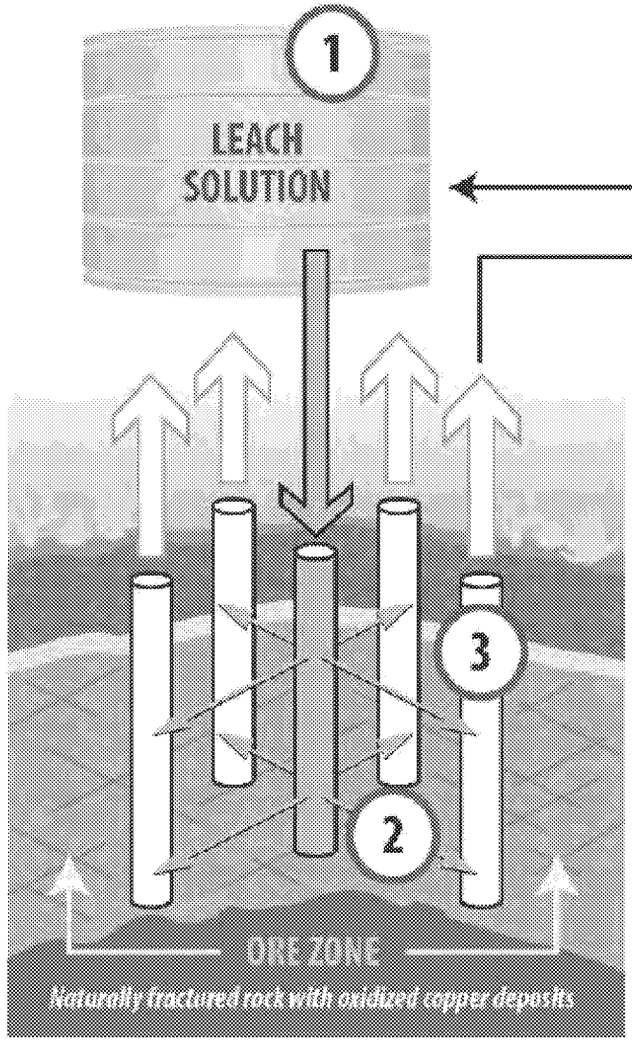


Excelsior MINING CORP

Play Video: ExcelsiorMining-2.mp4



In-Situ Copper Recovery Process (*in-situ* Latin "in place")



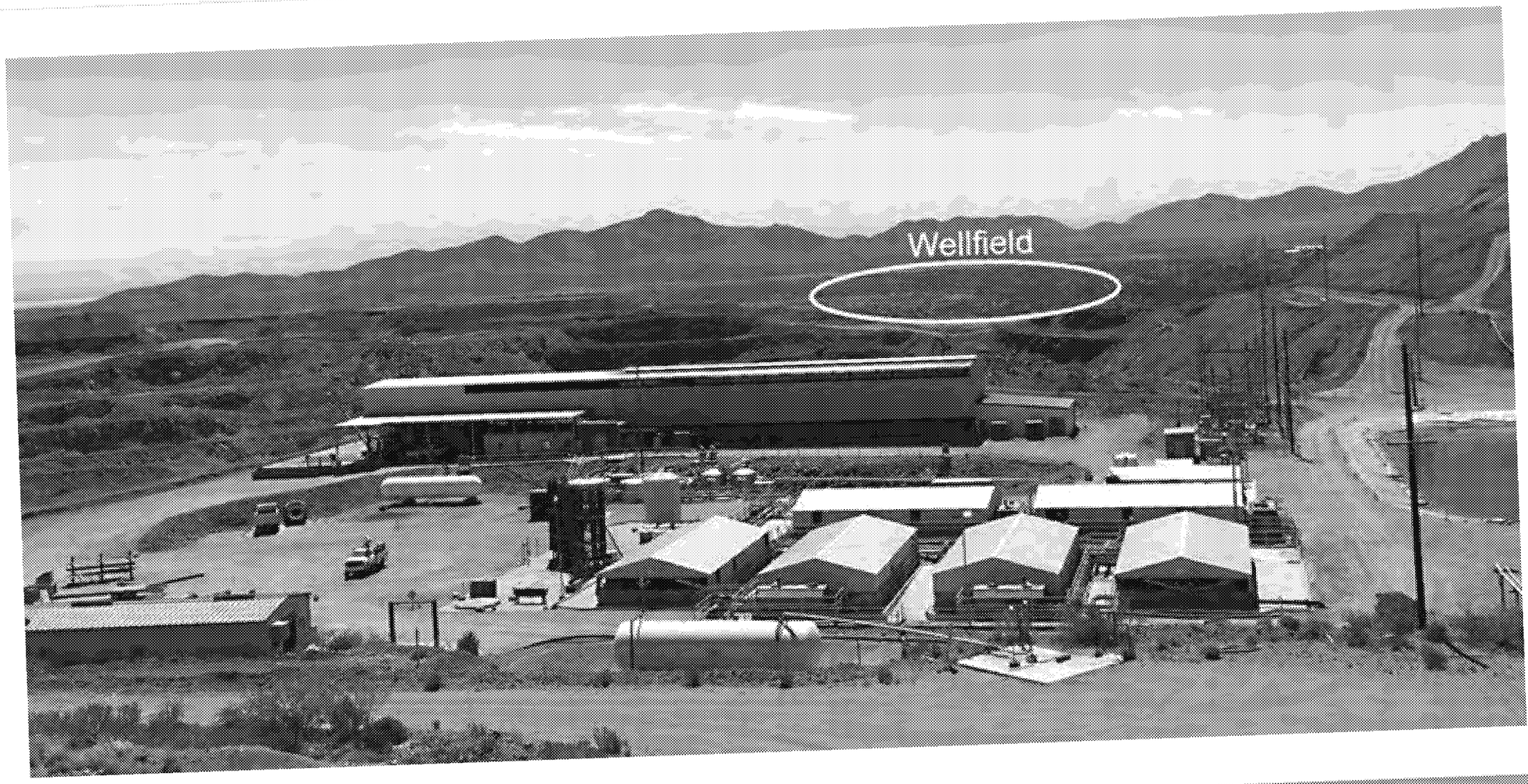
1. Leach solution is delivered into injection wells
2. The solution moves in a controlled way through naturally fractured rock
3. Extraction wells pump to recover copper-rich solution
4. Solution is pumped to the SX-EW Facility
5. Copper is extracted from the solution to create pure copper sheets, ready for sale
6. Remaining solution is recycled back into the process

FEATURES

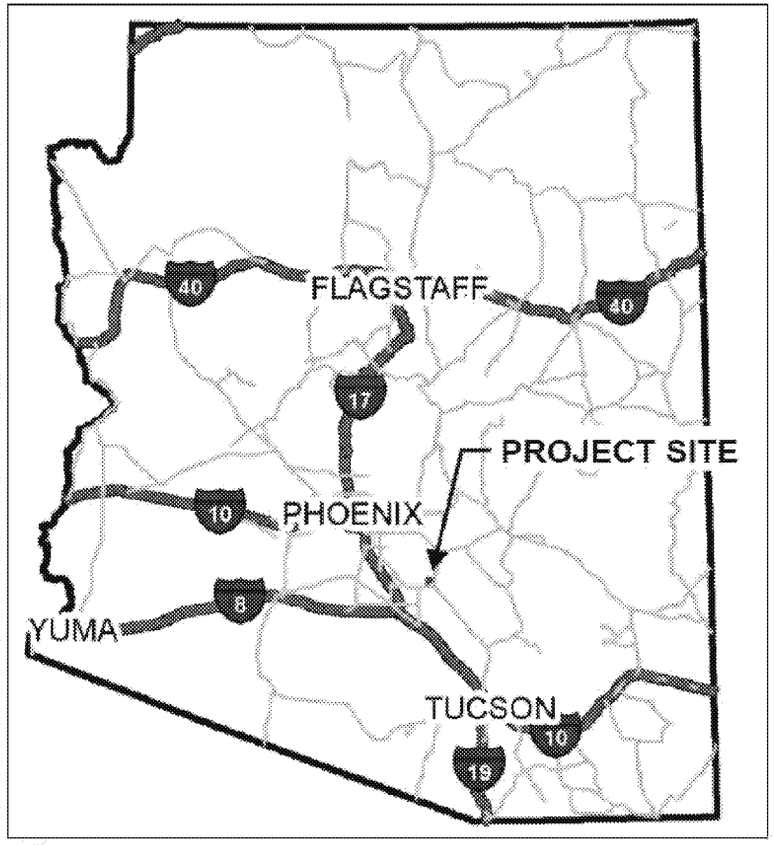
- proven mining technology
- no blasting, open pit or fracking
- processed solution is recycled
- on-site water recycling
- permitted & regulated by ADEQ & EPA

SX-EW Solution Extraction/Electro-Winning

Excelsior
MINING CORP



FLORENCE COPPER



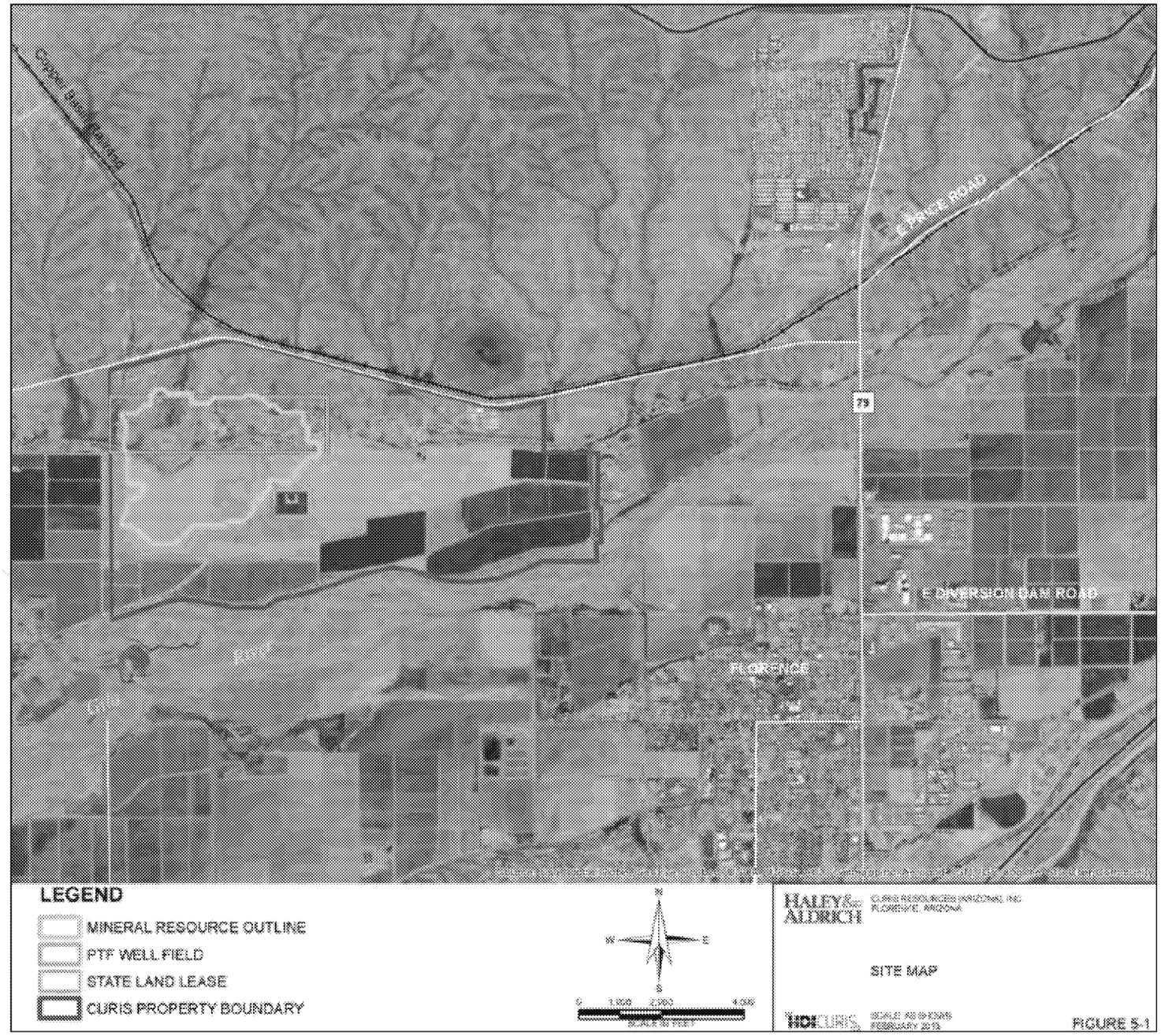


Figure 1-2: Florence Site Location Map

UIC Permitting History for the Florence Copper Project

- In 1998, the Region 9 DI Program issued a Class III UIC Permit to BHP Copper, Inc. authorizing the operations of injection wells for In-Situ Copper Recovery (ISCR) in a fractured bedrock aquifer that is a USDW.

§ 144.12 Prohibition of movement of fluid into underground sources of drinking water.

a) No owner or operator shall construct, operate, maintain, convert, plug, abandon, or conduct any other injection activity in a manner that allows the movement of fluid containing any contaminant into underground sources of drinking water, if the presence of that contaminant may cause a violation of any primary drinking water regulation…or may otherwise adversely affect the health of persons.

- Because the aquifer where the copper ore is located is a USDW and injection activities will release copper into the groundwater, EPA also granted an **aquifer exemption** for the proposed mining area.

§ 146.4 Criteria for exempted aquifers.

An aquifer or a portion thereof which meets the criteria for an "underground source of drinking water" in § 146.3 may be determined under § 144.7 of this chapter to be an "exempted aquifer" for Class I-V wells if it meets the criteria in paragraphs (a) through (c) of this section. Class VI wells must meet the criteria under paragraph (d) of this section:

(a) It does not currently serve as a source of drinking water; **and**

(b) It cannot now and will not in the future serve as a source of drinking water because:

(1) It is mineral, hydrocarbon or geothermal energy producing, or can be demonstrated by a permit applicant as part of a permit application for a Class II or III operation to contain minerals or hydrocarbons that considering their quantity and location are expected to be commercially producible.

[there are other criteria listed under § 146.4 (b)… § 146.4 (c) and (d)…]

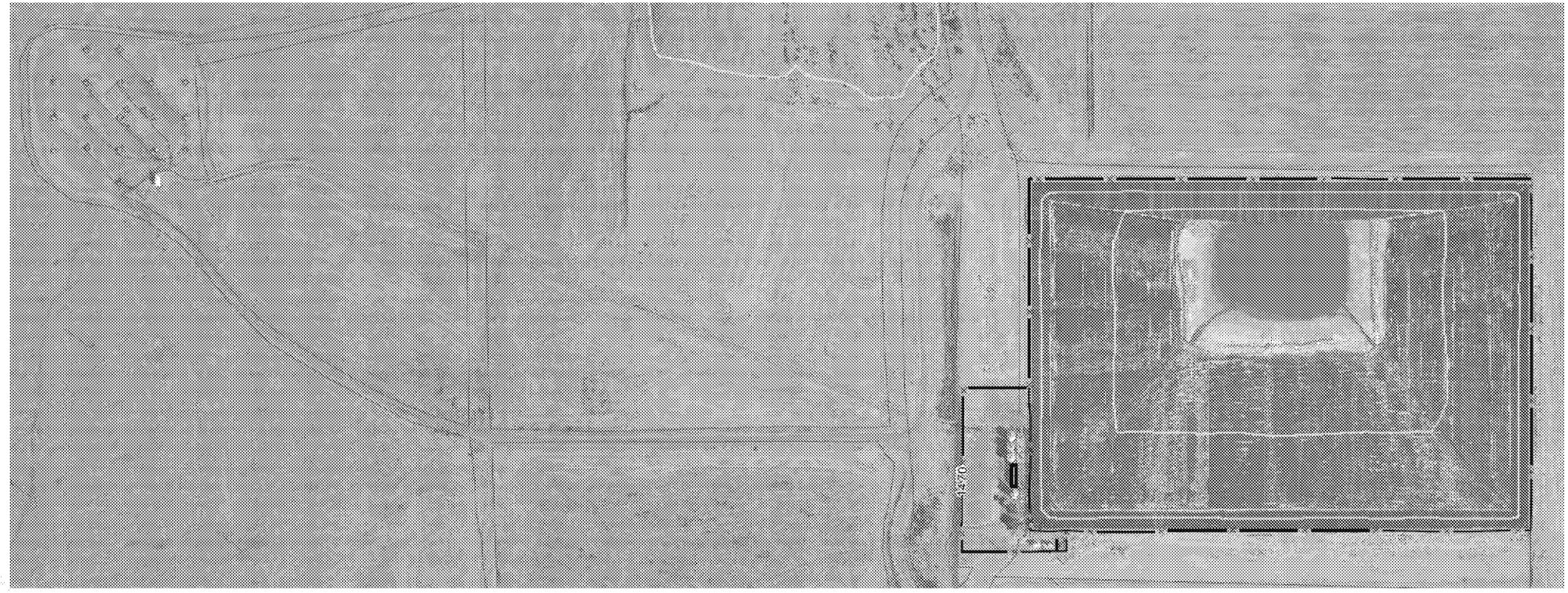
FLORENCE COPPER

LEGEND

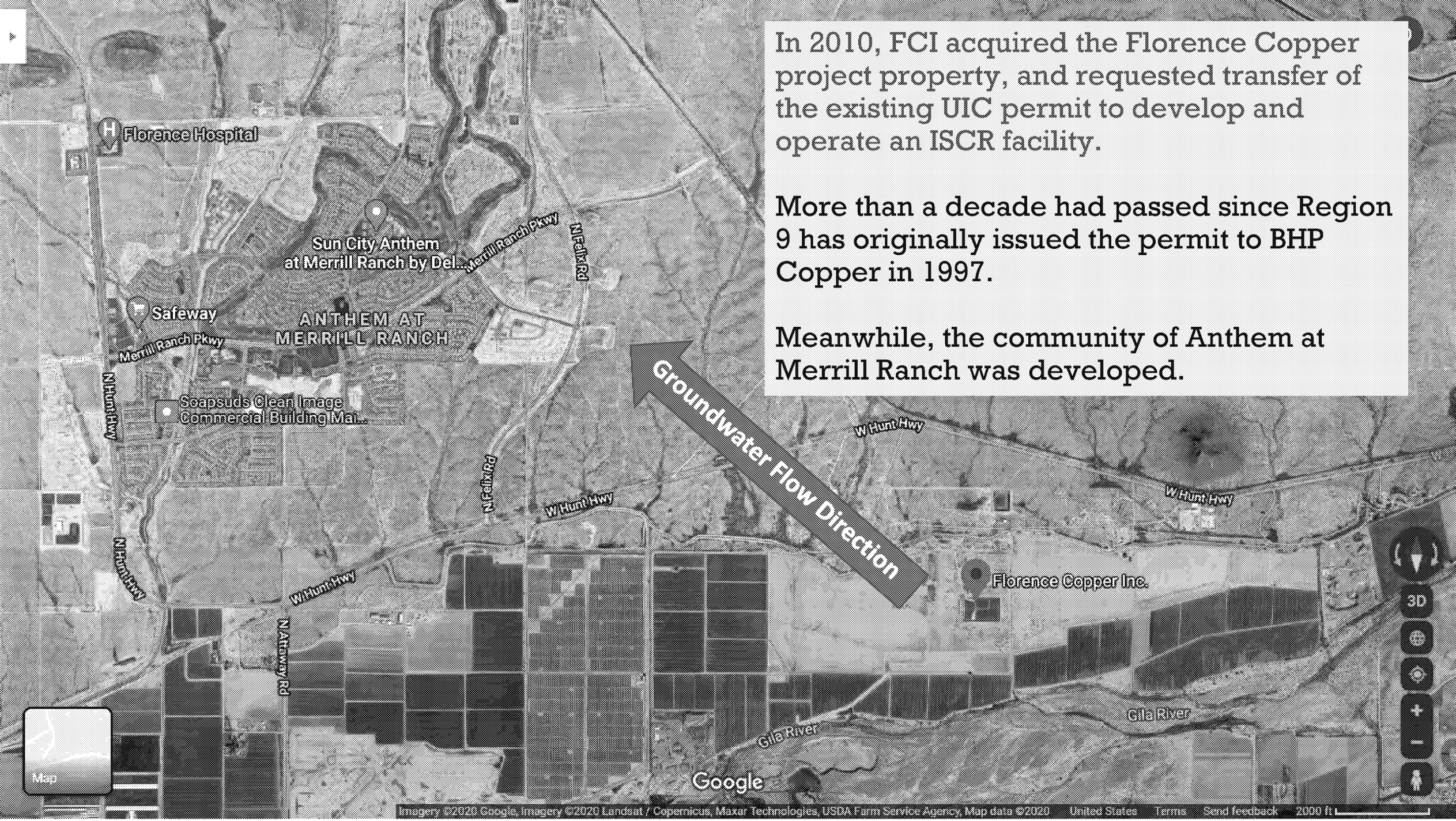
- AQUIFER EXEMPTION AREA
- PROPERTY BOUNDARY
- STATE MINE LEASE BOUNDARY
- PTF WELL FIELD
- AREA OF REVIEW
- CONOCO UNDERGROUND MINE WORKINGS

UIC Permitting History for the Florence Copper Project

- BHP Copper drilled 4 Class III injection wells, 9 recovery wells, and 7 observation wells into the copper-ore-bearing bedrock aquifer and operated a pilot project to demonstrate hydraulic control as required by the UIC permit.



- However, BHP Copper deferred developing the full-scale facility and later sold the property.



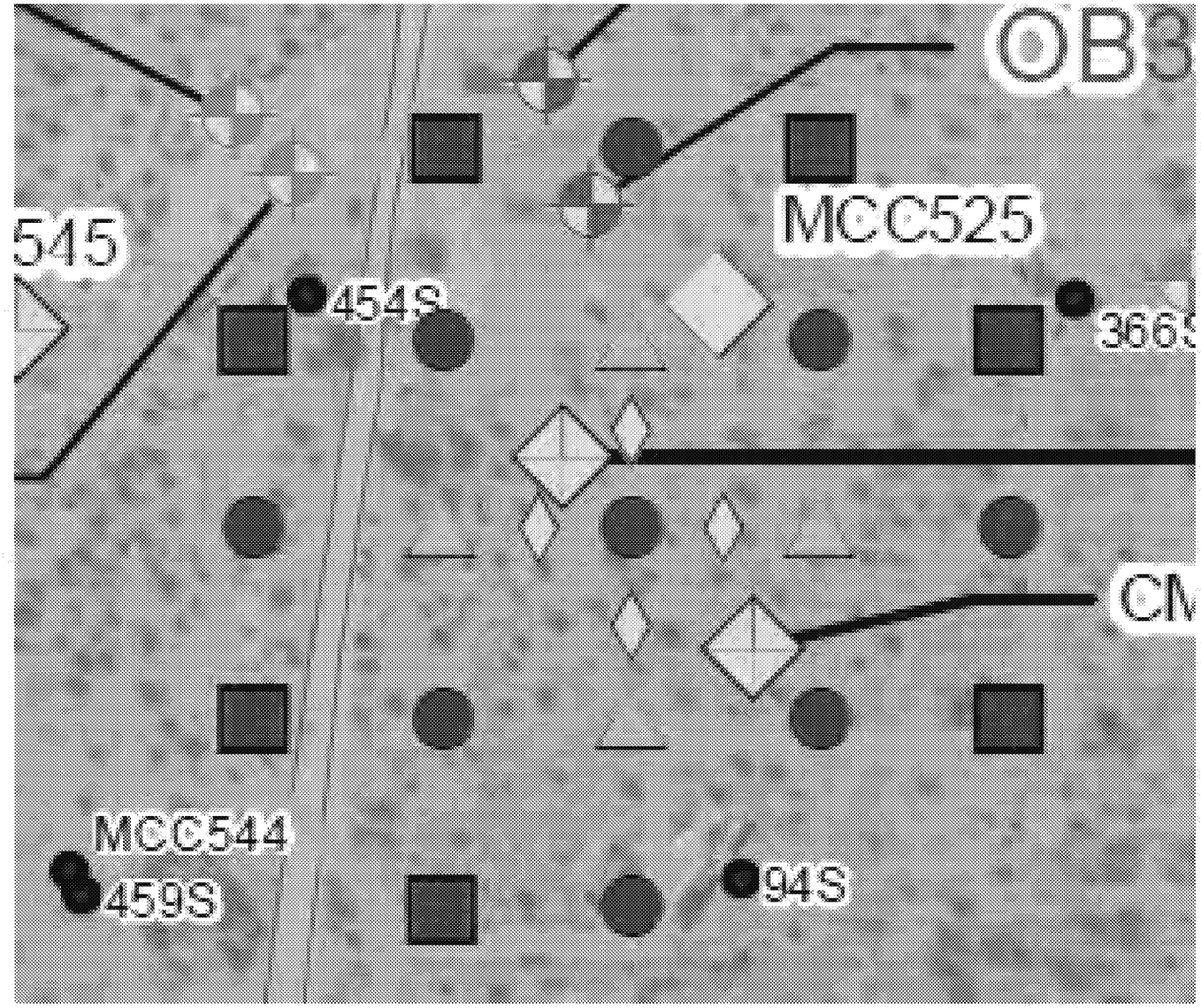
ED_005364K_00000031-00020

Production Test Facility (PTF)

FLORENCE COPPER

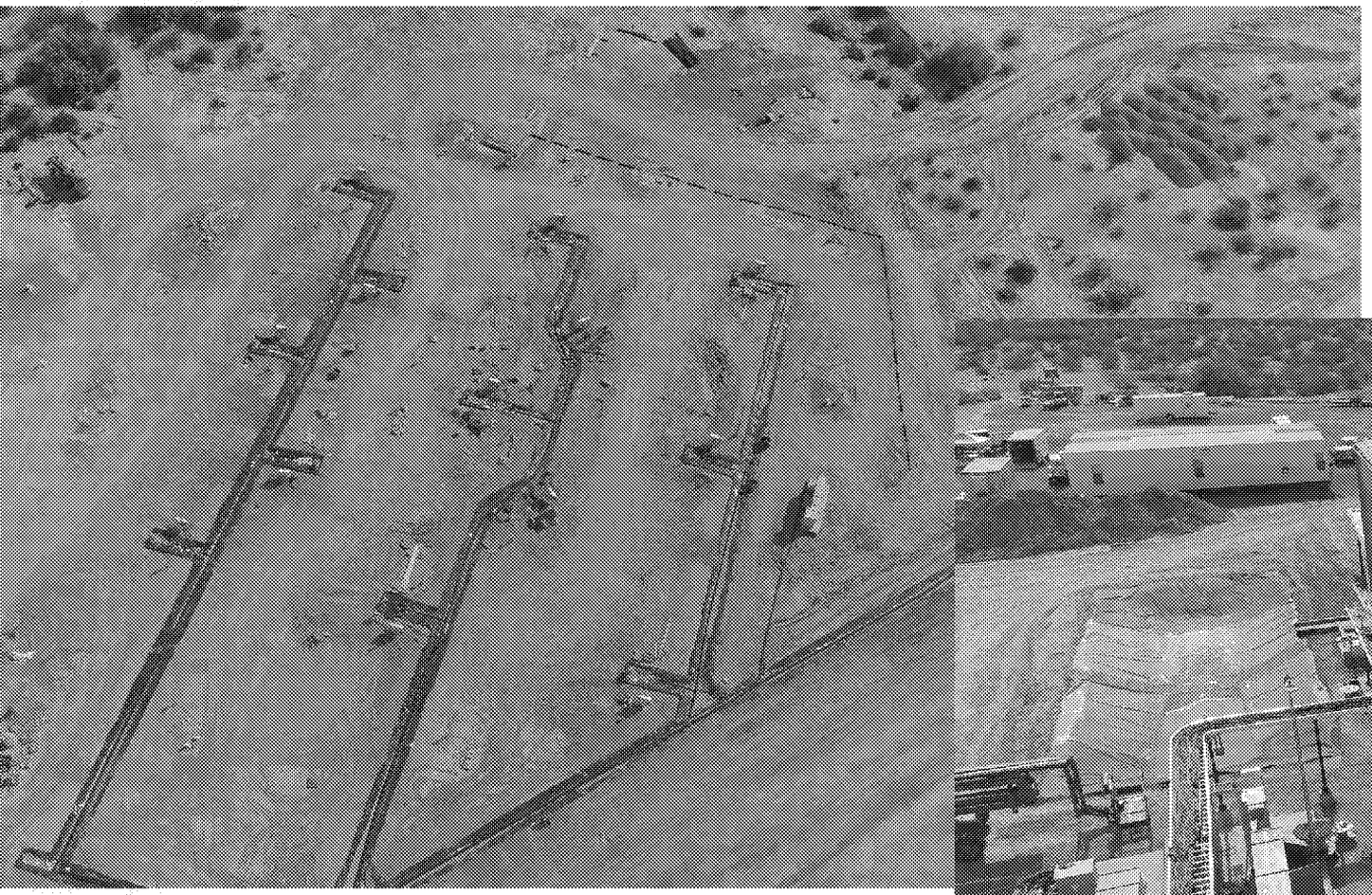
PROPOSED TEST WELLS

- INJECTION
- OBSERVATION
- RECOVERY
- MULTI-LEVEL SAMPLING WELL



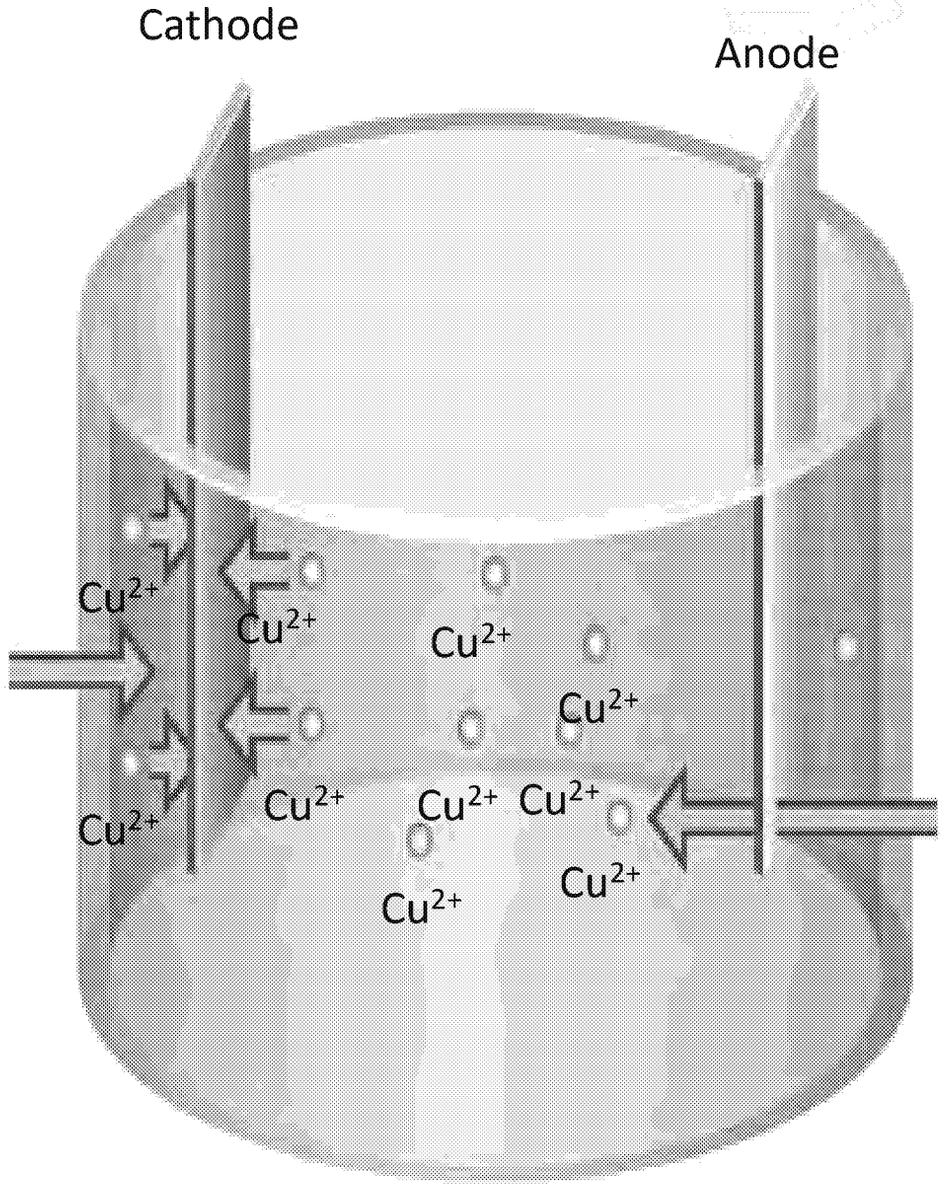
FLORENCE COPPER

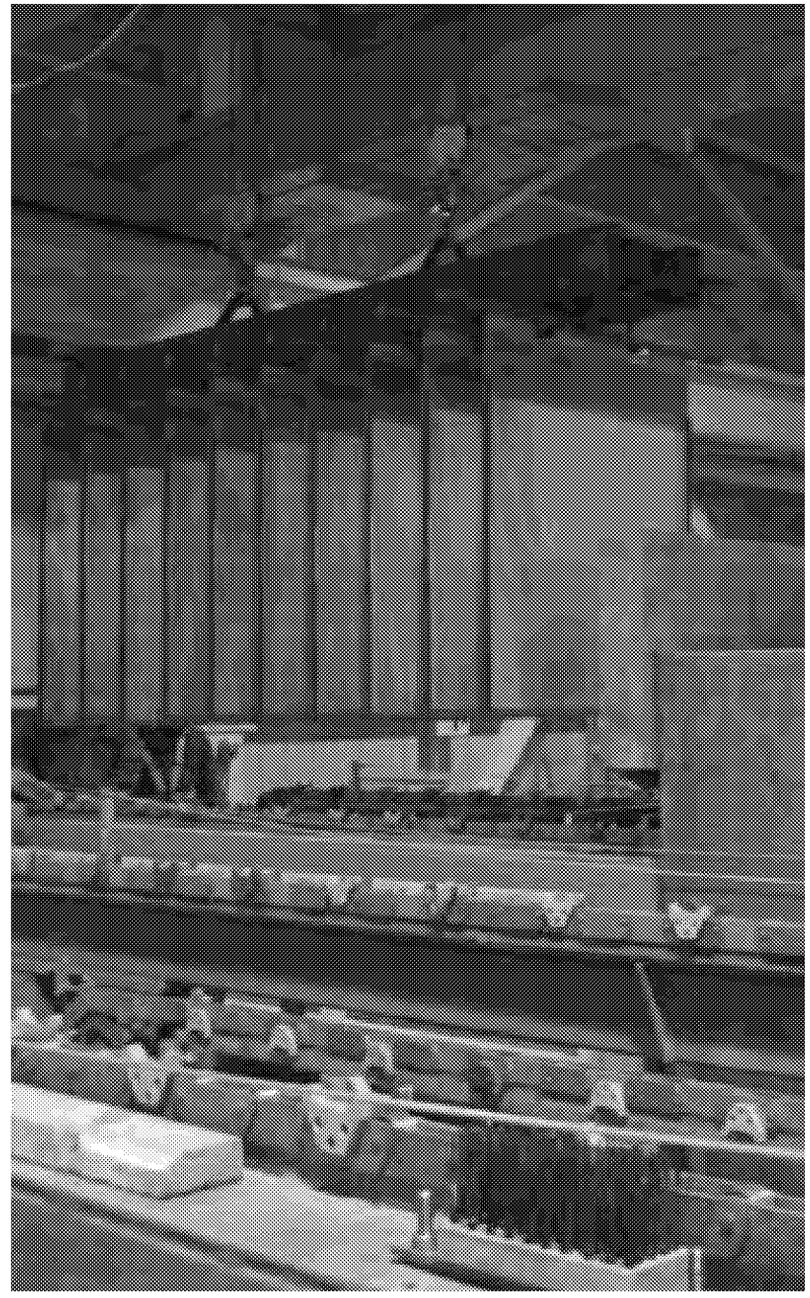
Play Video: FlorenceCopperVideo.mp4

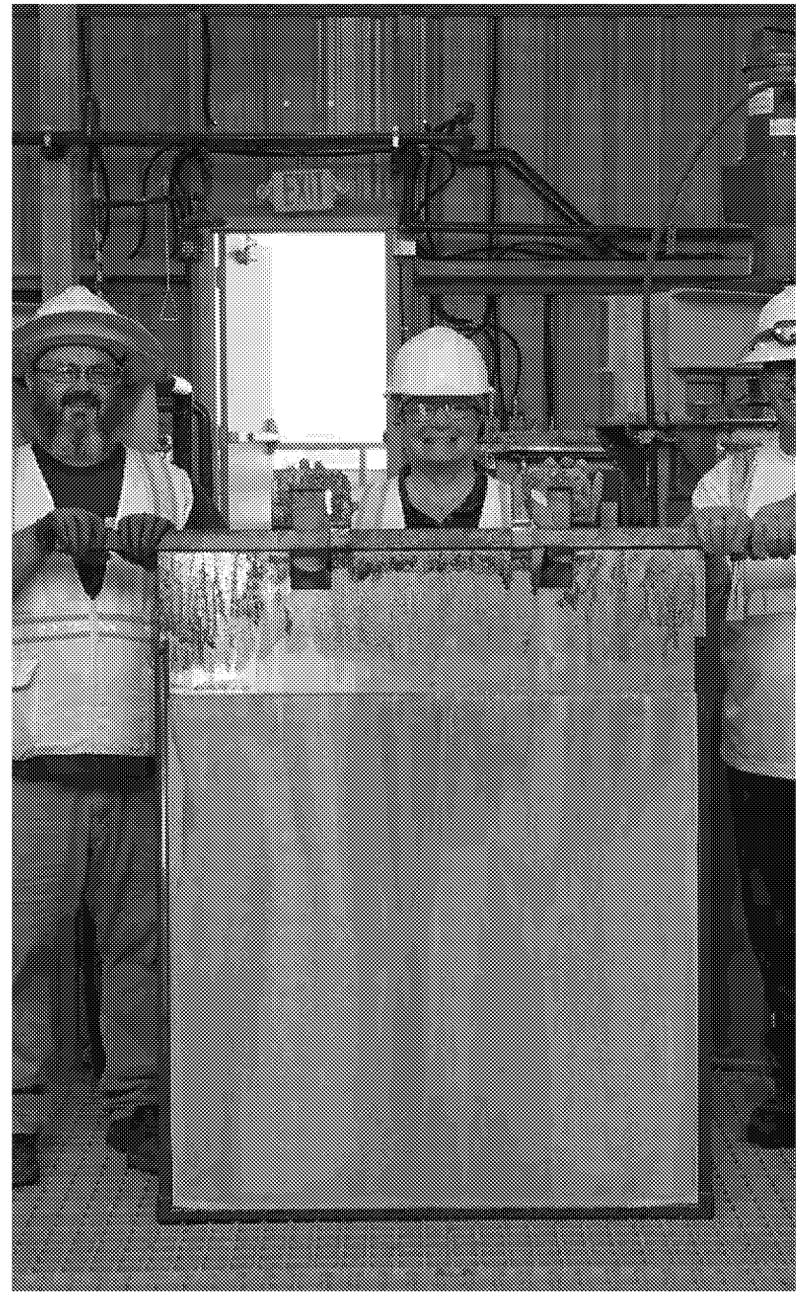


Electrowinning Process

- Cathodes and anodes are aligned inside a tank filled with copper-bearing electrolytic solution.
- Electrical current creates a movement of cations towards the cathode.
- As the process continues the positively charged copper ions will plate on the cathodes.







Inspection Procedure for this type of facility

Review Final Permit

WELL CONSTRUCTION AND LOCATION

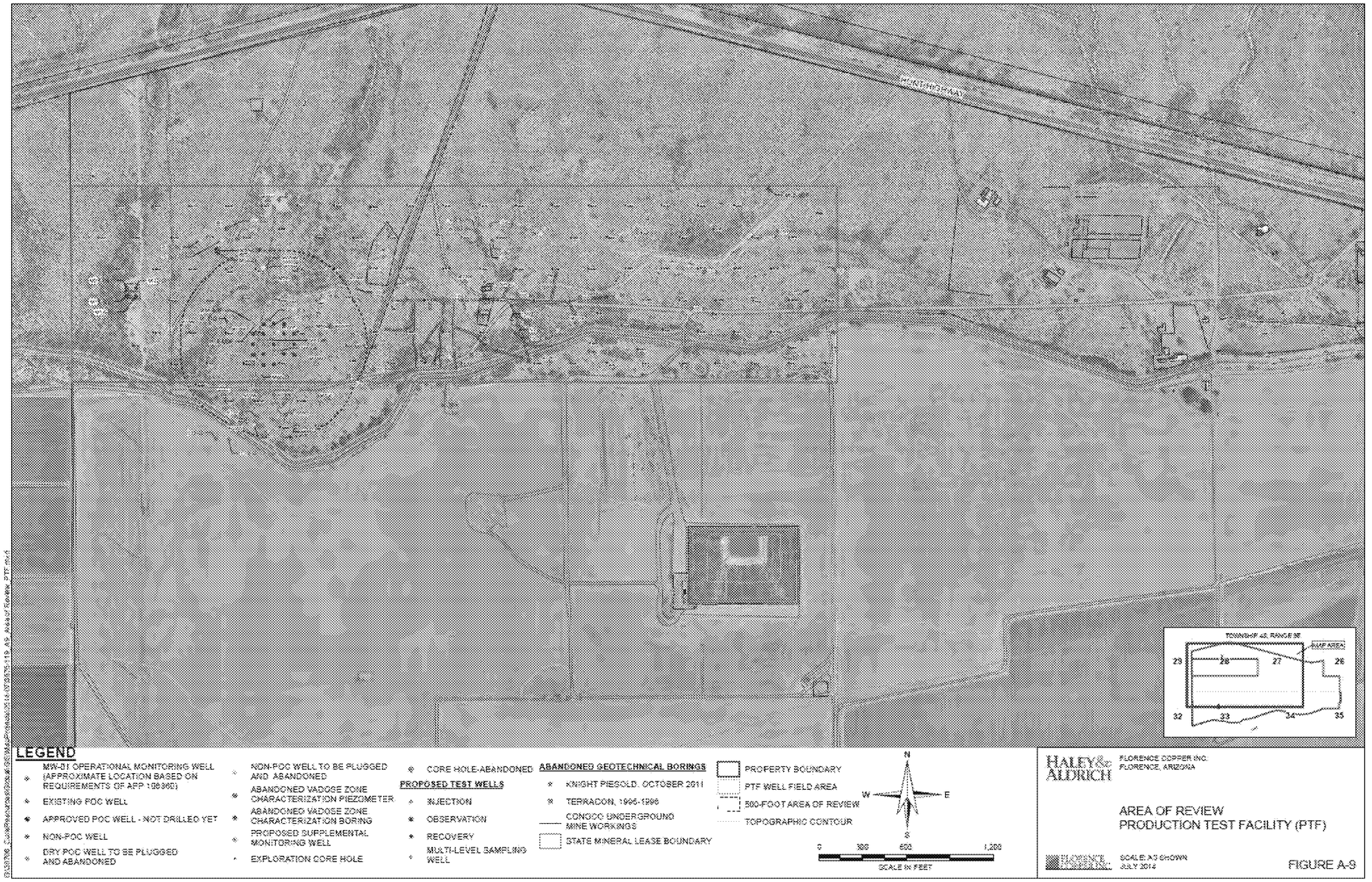
Location of PTF Wells

The PTF's four (4) injection, nine (9) recovery, seven (7) observation, and four (4) multi-level sampling wells shall be constructed within the designated area delineated in **Figure A-9** in Appendix A.

Important info can also be found in the

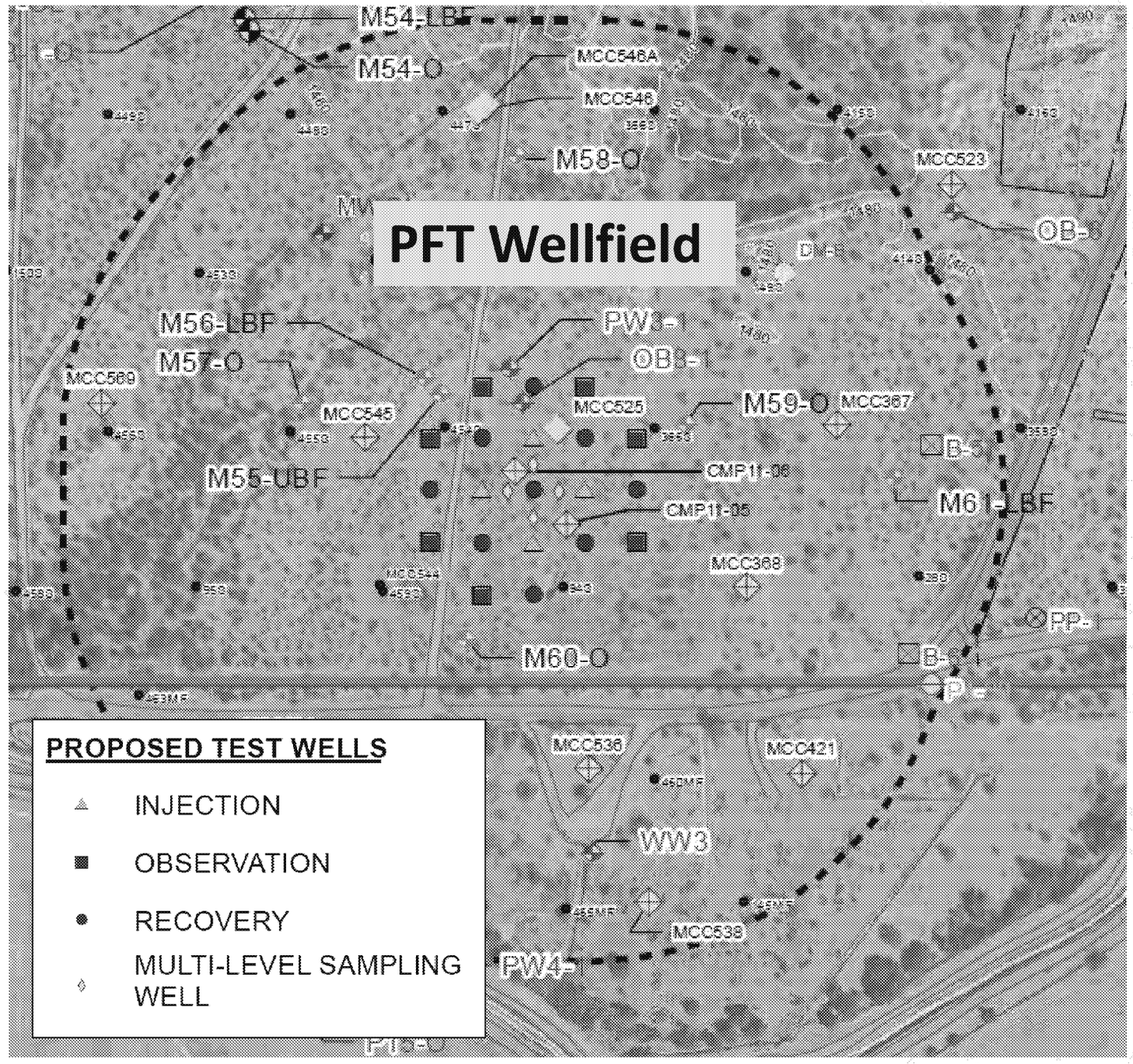
- Draft Permit Statement of Basis and
- the Permit Application

Figure A-9 in Appendix A



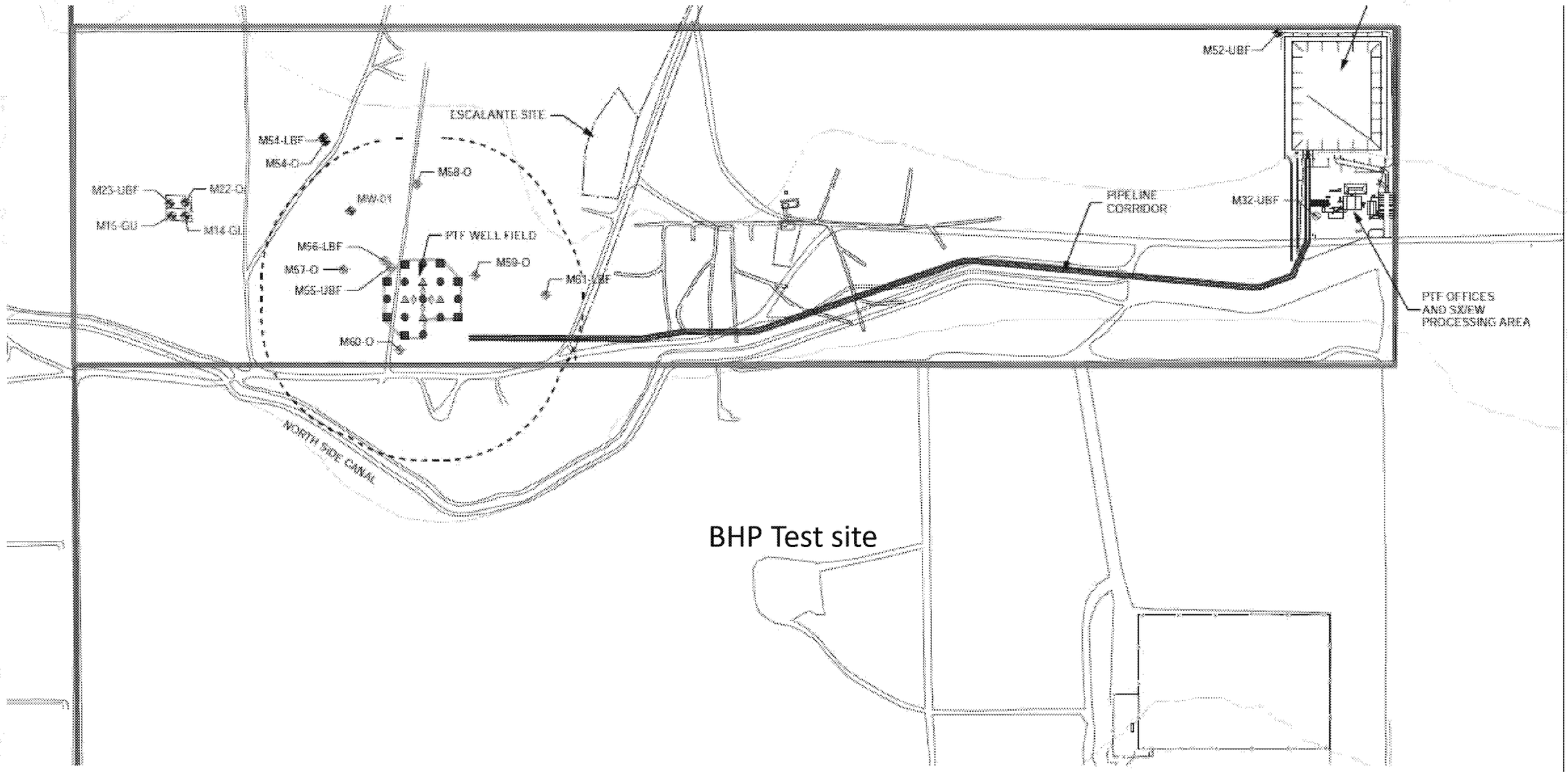
FLORENCE COPPER

Production Test Facility (PTF)



LEGEND

- AQUIFER EXEMPTION AREA
- PROPERTY BOUNDARY
- STATE MINE LEASE BOUNDARY
- PTF WELL FIELD
- AREA OF REVIEW
- CONOCO UNDERGROUND MINE WORKINGS



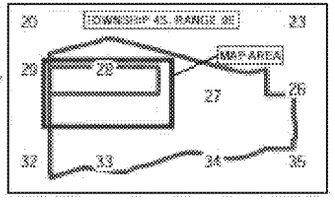
LEGEND

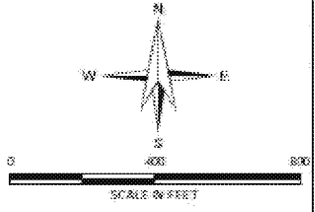
- MW-01 OPERATIONAL MONITORING WELL (APPROXIMATE LOCATION BASED ON REQUIREMENTS OF APP 106360)
- EXISTING PTF POC WELL
- DRY POC WELL TO BE PLUGGED AND ABANDONED
- APPROVED POC WELL - NOT DRILLED YET
- SUPPLEMENTAL MONITORING WELL

PROPOSED TEST WELLS

- INJECTION
- OBSERVATION
- RECOVERY
- MULTI-LEVEL SAMPLING WELL

- CONOCO UNDERGROUND MINE WORKINGS
- PTF WELL FIELD
- STATE MINERAL LEASE BOUNDARY
- PROPERTY BOUNDARY
- 500 FOOT AREA OF REVIEW
- CONTOUR (10 FT)





HALEY & ALDRICH

FLORENCE COPPER INC.
FLORENCE, ARIZONA

EXISTING AND PROPOSED POINT OF COMPLIANCE, OPERATIONAL MONITORING, AND SUPPLEMENTAL MONITORING WELLS

SCALE: AS SHOWN
JULY 2014

FIGURE P-1

Inspection Procedure for this type of facility
Review Final Permit

Injection Monitoring and Controls

- an isolation valve at each injection well;
- a pressure transducer at the wellhead;
- a pressure transducer to measure annular pressure above the packer;
- a pressure transducer to measure pressure in the injection zone.
- a flow meter at each injection well for measuring flow rates (gpm);
- a valve at each injection well for controlling flow;
- a flow meter at each injection manifold for measuring flow rates (gallons per minute [gpm]);
- a totalizing flow meter for measuring cumulative flow (gallons) into each injection manifold;

A schematic depicting well field controls is included as Figure 1, and well controls as Figure 2.

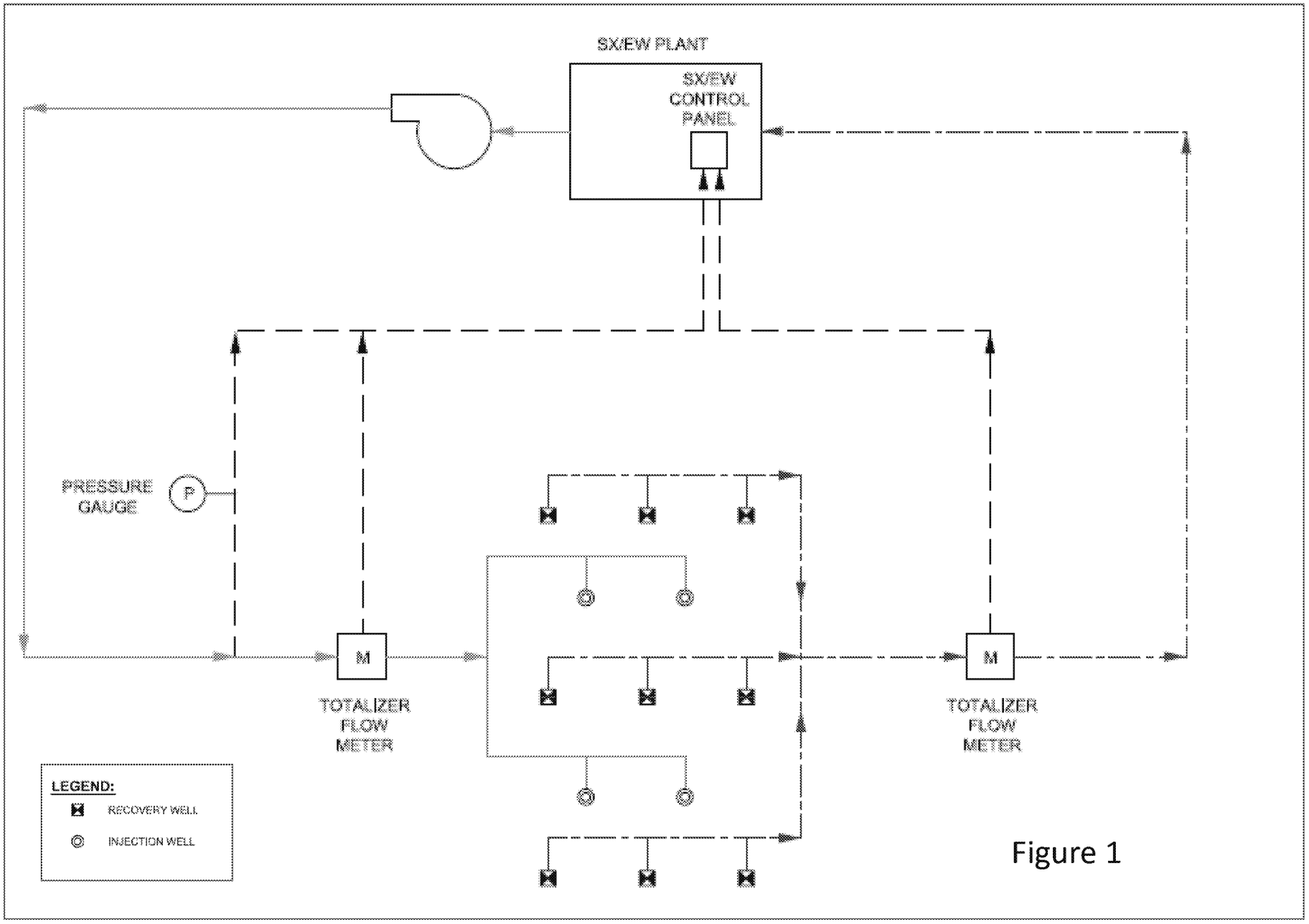

SX/EW PLANT
SX/EW CONTROL PANEL
PRESSURE GAUGE
P
M
TOTALIZER FLOW METER
M
TOTALIZER FLOW METER
LEGEND:
RECOVERY WELL
INJECTION WELL

Figure 1

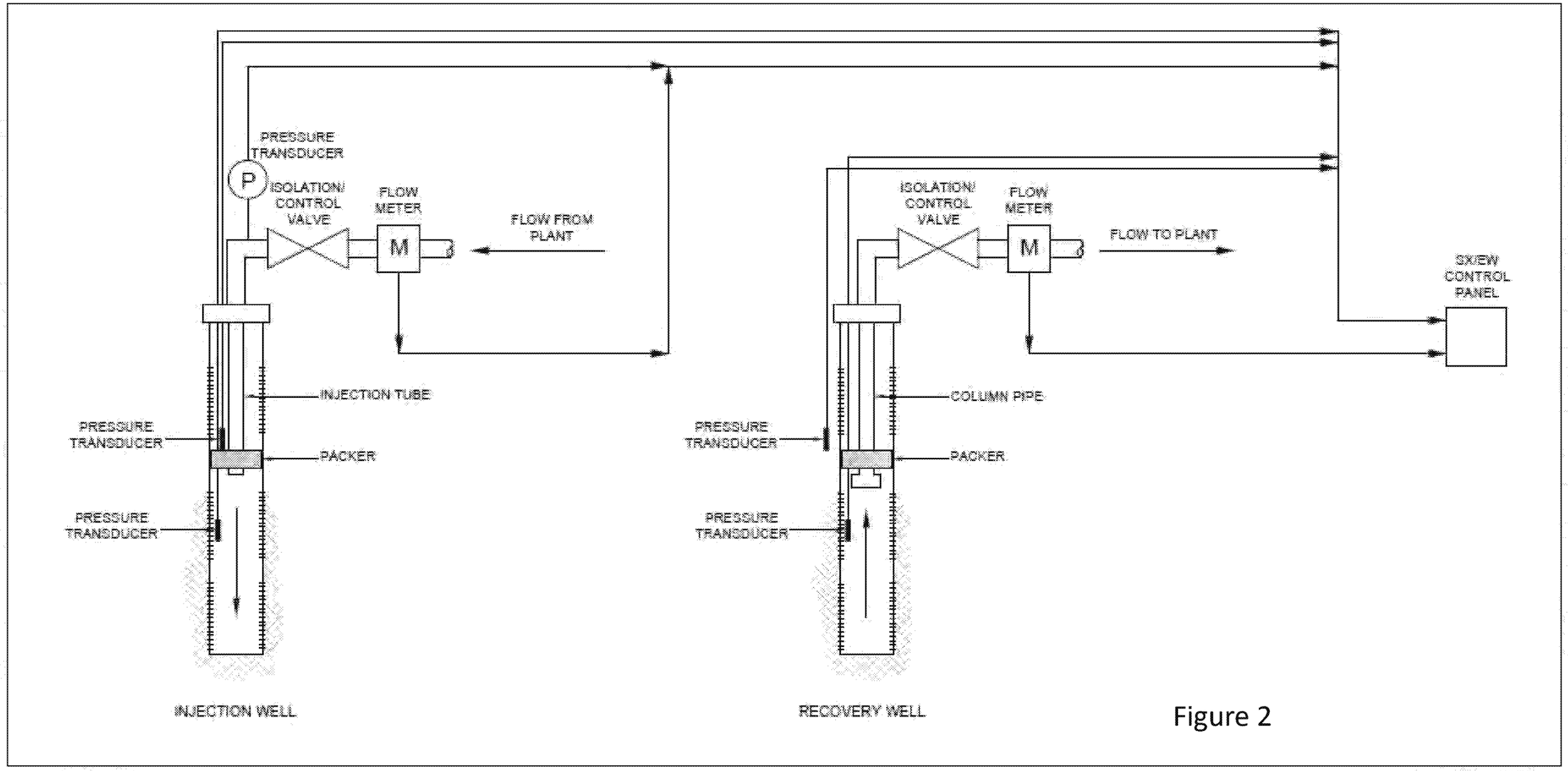
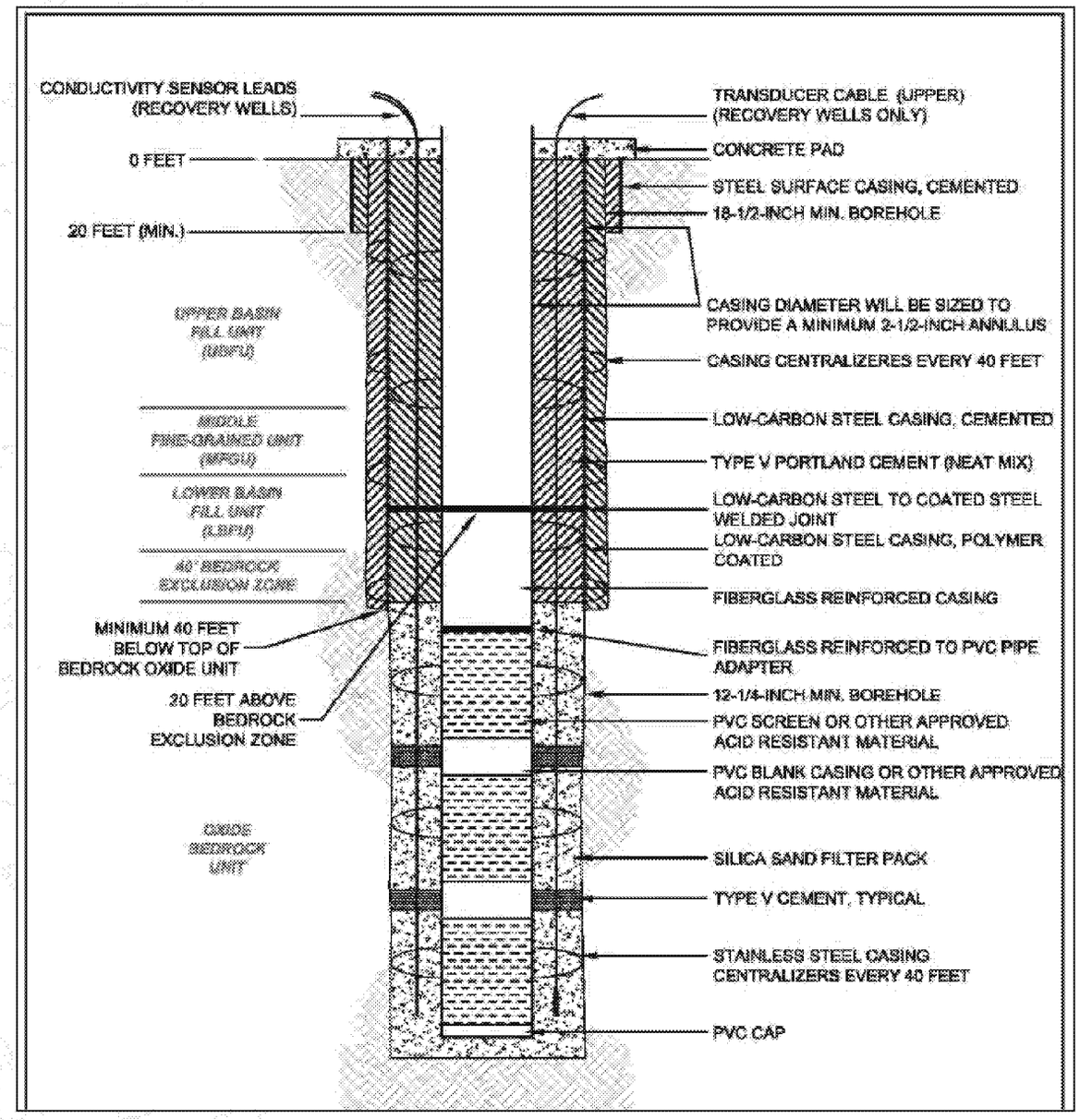

PRESSURE TRANSDUCER
P
ISOLATION/ CONTROL VALVE
FLOW METER
M
FLOW FROM PLANT
INJECTION TUBE
PRESSURE TRANSDUCER
PACKER
PRESSURE TRANSDUCER
INJECTION WELL
ISOLATION/ CONTROL VALVE
FLOW METER
M
FLOW TO PLANT
SX/EW CONTROL PANEL
COLUMN PIPE
PRESSURE TRANSDUCER
PACKER
PRESSURE TRANSDUCER
RECOVERY WELL

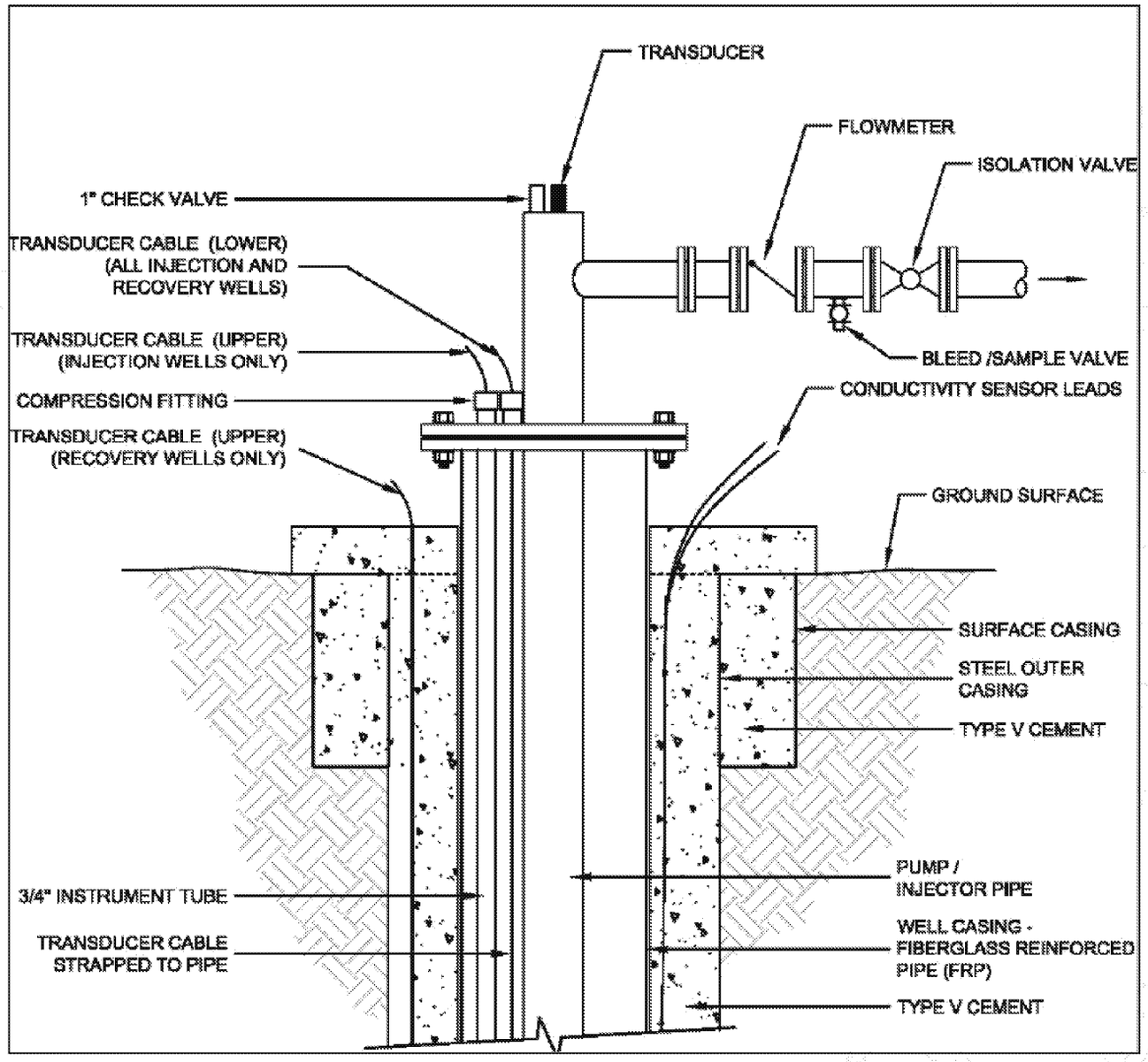
Figure 2

Well Construction Information

Injection and Recovery Wells



Injection and Recovery Wellhead



Inspection Procedure for this type of facility

Review Final Permit

WELL OPERATION

Operations Plan- Hydraulic Control

Injection and recovery rates will be approximately 240 and 300 gallons per minute (gpm), respectively.

During PTF operations, the injection rate shall not exceed 240 gpm, and the extraction rate shall not fall below 110 percent of the injection rate on a daily average basis without prior written approval of a lower percentage from EPA.

Every 24 hours, the totalized flows from all of the injection wells will be summed and compared to the summed totalized flows from all of the recovery wells.

If the summed total flow out of the well field exceeds the total flow into the well field, and if head elevations observed in the observation wells are greater than head elevations observed at the paired recovery wells, hydraulic control is confirmed.

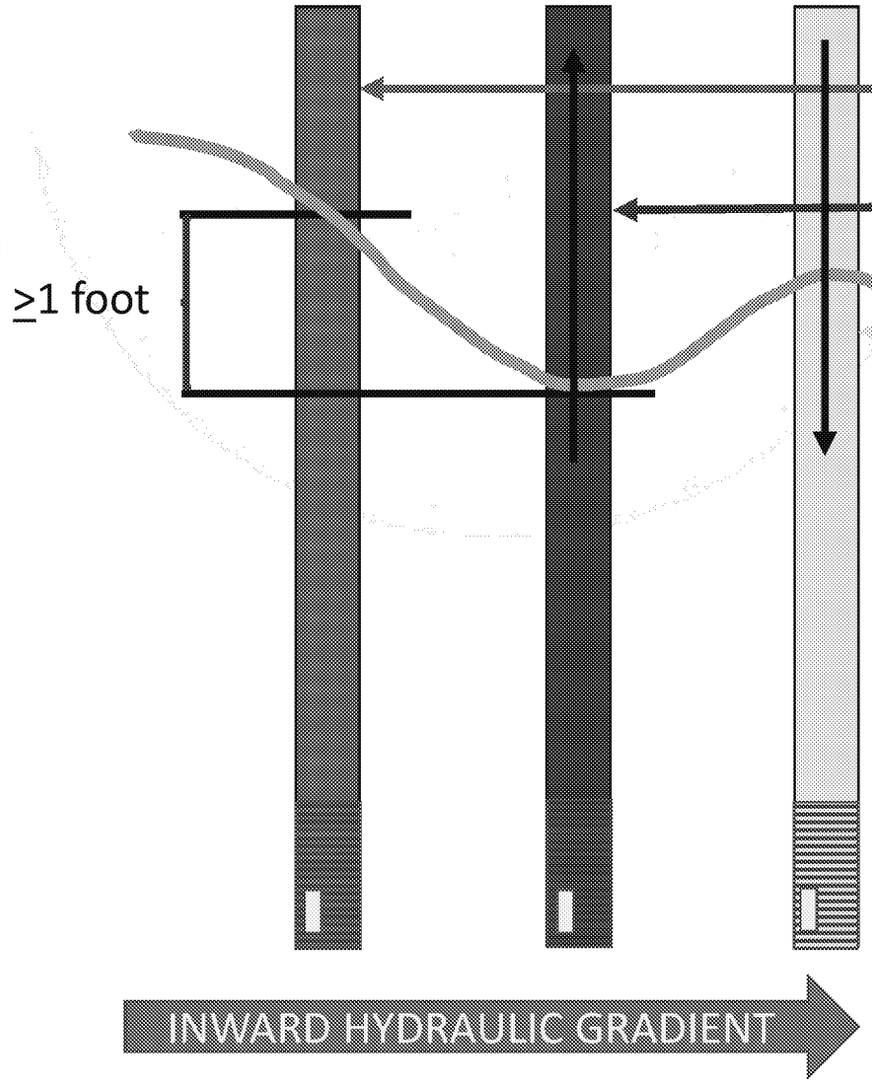
Inspection Procedure for this type of facility

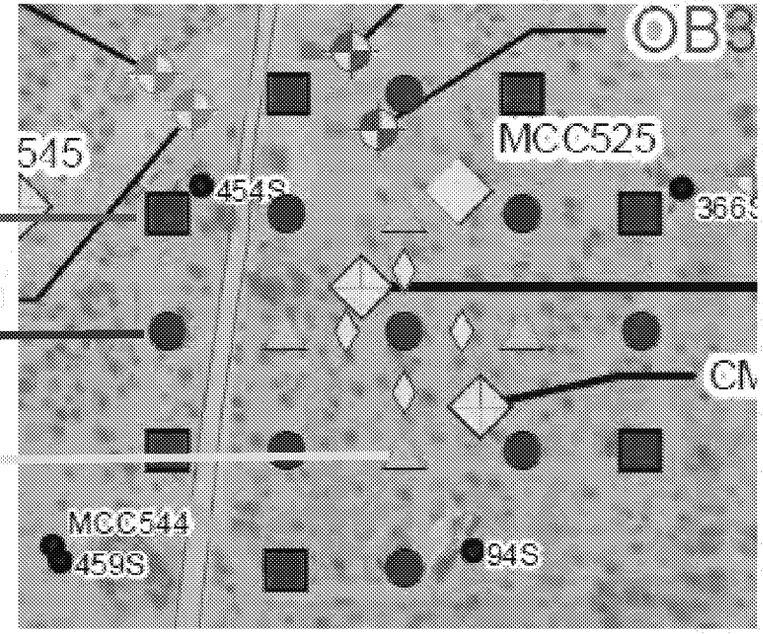
Review Final Permit

Operations Plan – Hydraulic Control continued

An inward gradient of at least one foot between observation and recovery wells must be maintained for demonstrating hydraulic control.

Head monitoring will be accomplished using pressure transducers placed in both the observation wells and recovery wells from which average daily head measurements will be recorded.





PROPOSED TEST WELLS

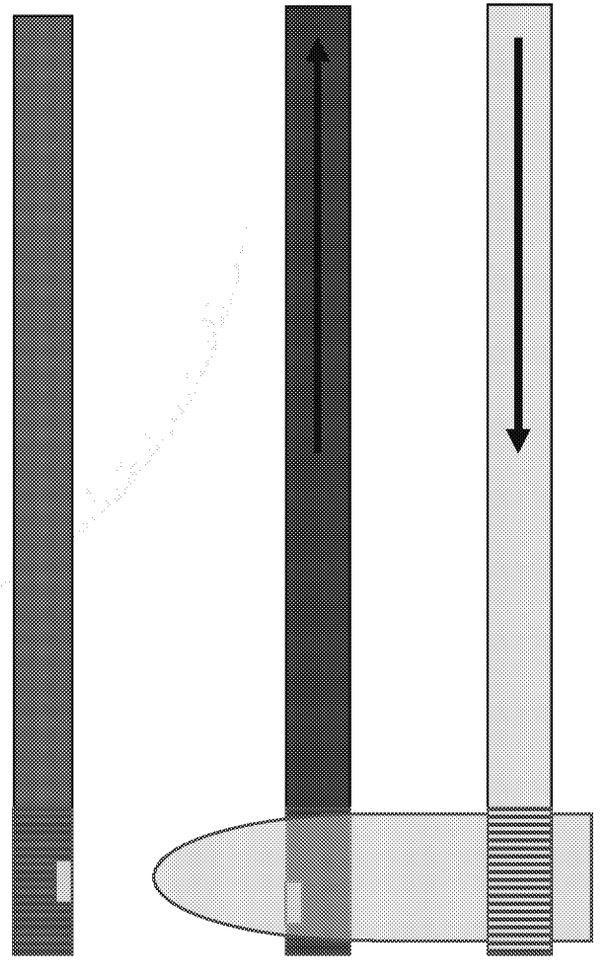
- INJECTION
- OBSERVATION
- RECOVERY
- MULTI-LEVEL SAMPLING WELL
- POTENTIOMETRIC SURFACE

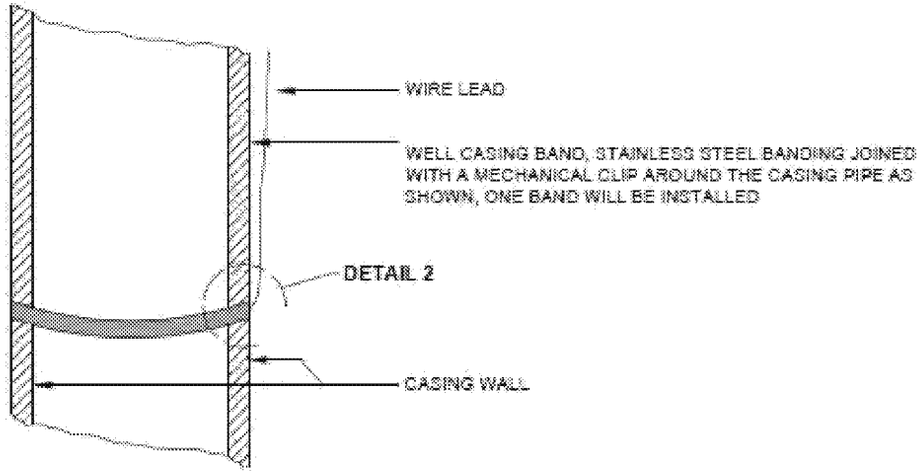
MONITORING PROGRAM

Hydraulic Control Monitoring Wells

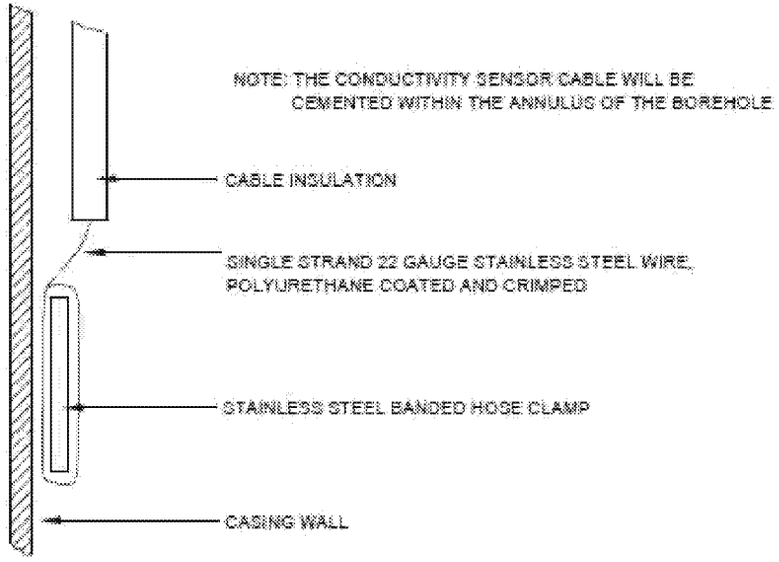
- In addition, the Permittee shall monitor bulk electrical conductivity in the observation wells to verify that hydraulic control is maintained and to detect any excursion

- Bulk conductivity readings in the observation wells shall not significantly exceed baseline conductivity to confirm hydraulic control.





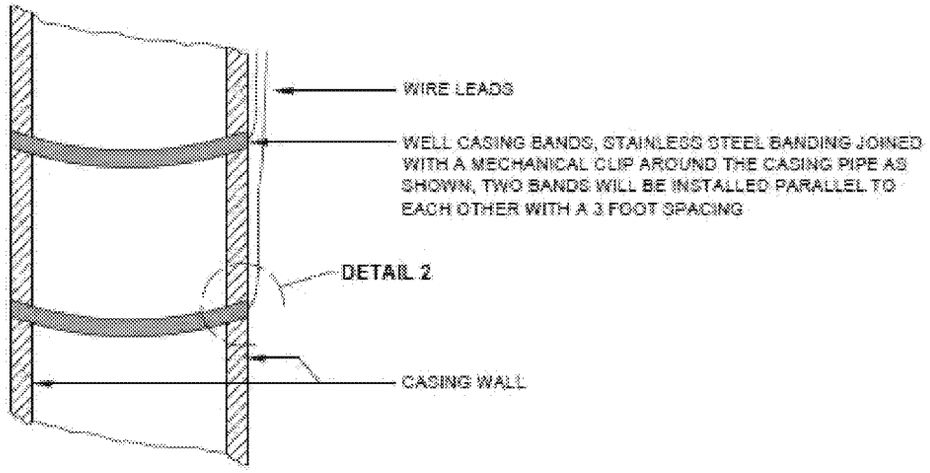
DRAWING M-8
CONDUCTIVITY SENSOR DEVICE DETAIL 1
NOT TO SCALE



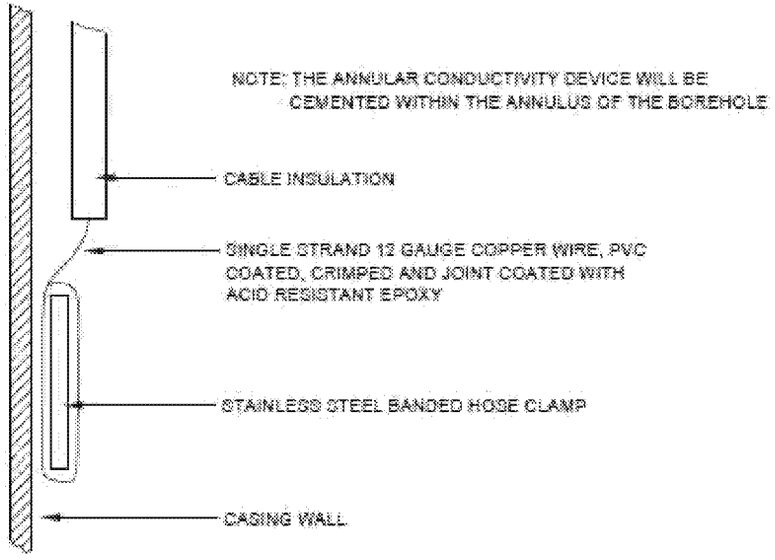
DRAWING M-9
CONDUCTIVITY SENSOR DEVICE DETAIL 2
NOT TO SCALE

Conductivity sensors will be attached to the screen of recovery wells, observation wells, and multi-level sampling wells to facilitate electrical resistivity profiling of the injection zone during injection and recovery.

During PTF operations, the Permittee shall measure bulk electrical conductivity in the observation wells at the screens on a daily basis.



DRAWING M-6
ANNULAR CONDUCTIVITY DEVICE DETAIL 1
NOT TO SCALE



DRAWING M-7
ANNULAR CONDUCTIVITY DEVICE DETAIL 2
NOT TO SCALE

Continuous verification of external mechanical integrity for Monitoring Wells

Each observation and multilevel sampling well shall be equipped with an annular conductivity device (ACD) to detect vertical channels adjacent to the well bore.

The ACD will consist of a pair of metal bands spaced approximately three (3) feet apart and connected to electrical wires that extend to the surface.

Conductivity Monitoring

- Annular conductivity monitoring at least once per quarter

Inspection Procedure for this type of facility

Review Final Permit

MONITORING PROGRAM

- Mechanical Integrity
  Continuous monitoring or recording requirements

- Schedule for Demonstrations of Mechanical Integrity

- Injection Pressure Limitation

Water Quality Monitoring Wells.

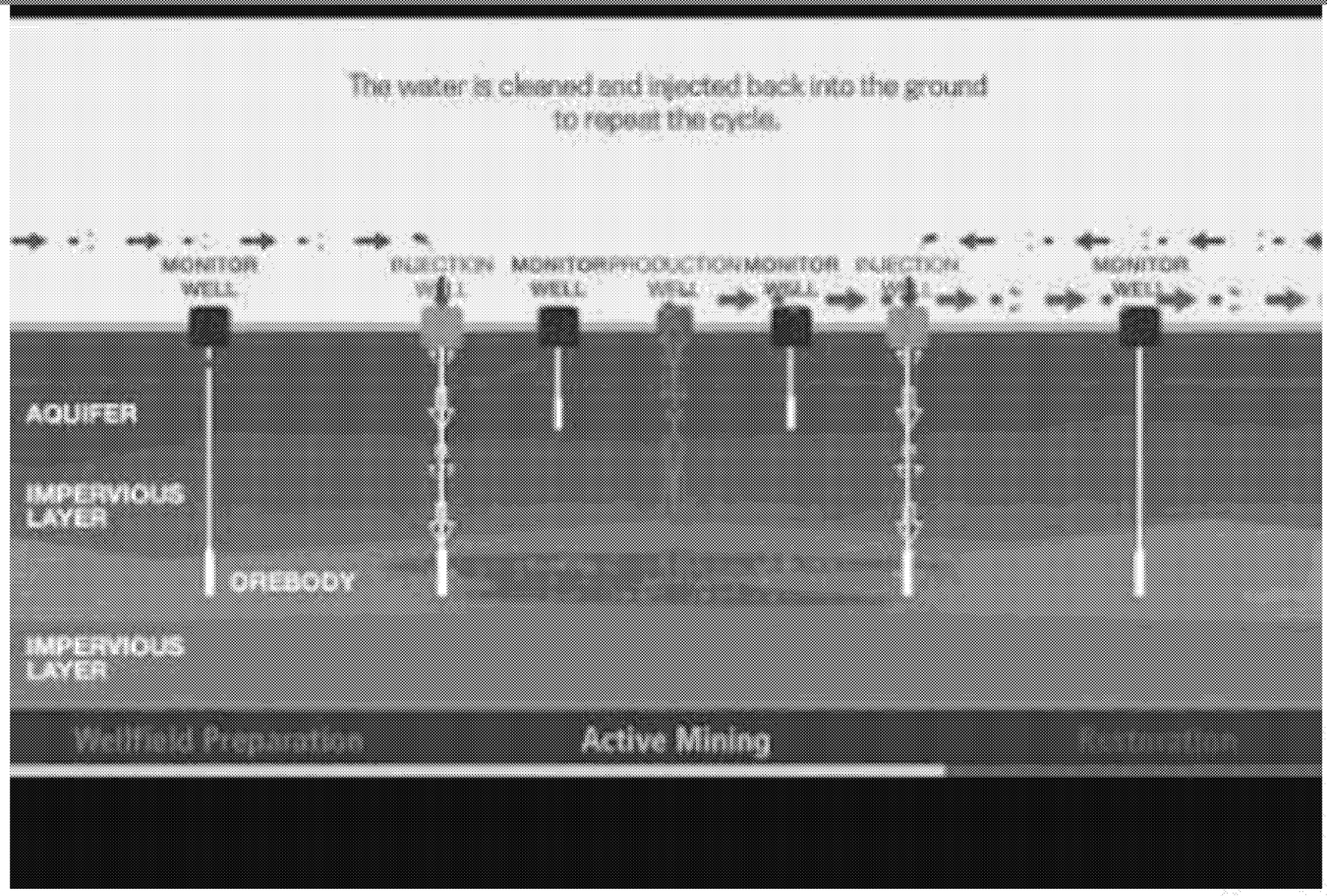
- Do you want to collect fluid samples?
- Monitoring well locations
- List of analytes
- Sampling equipment, preservatives
- Sample containers – be prepared for split samples
- QAPP – Sampling Plan, SOPs
- Chain of Custody form

Uranium Energy Corp

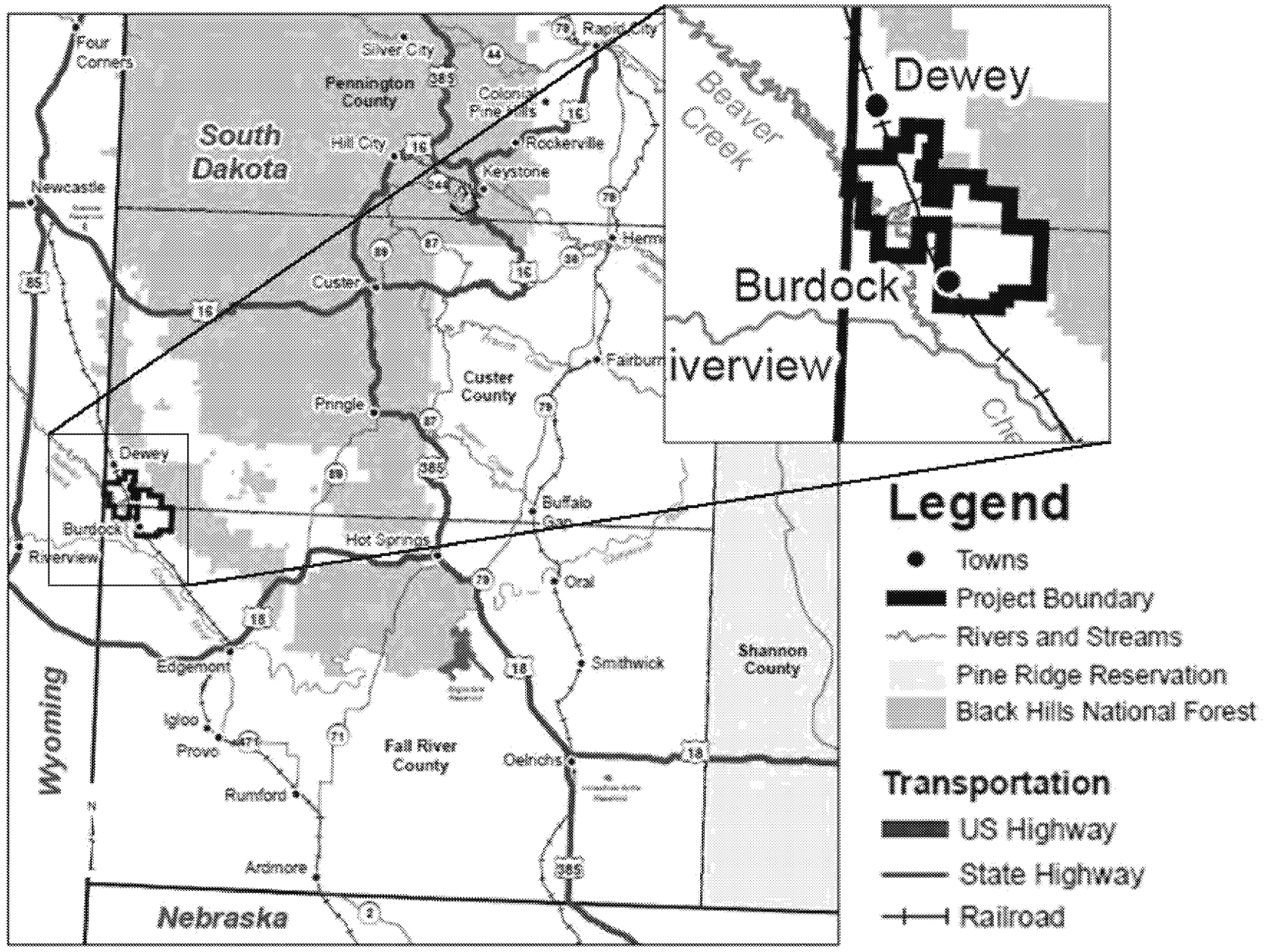
Play video: In-Situ Recovery of Uranium

In-Situ Recovery of Uranium

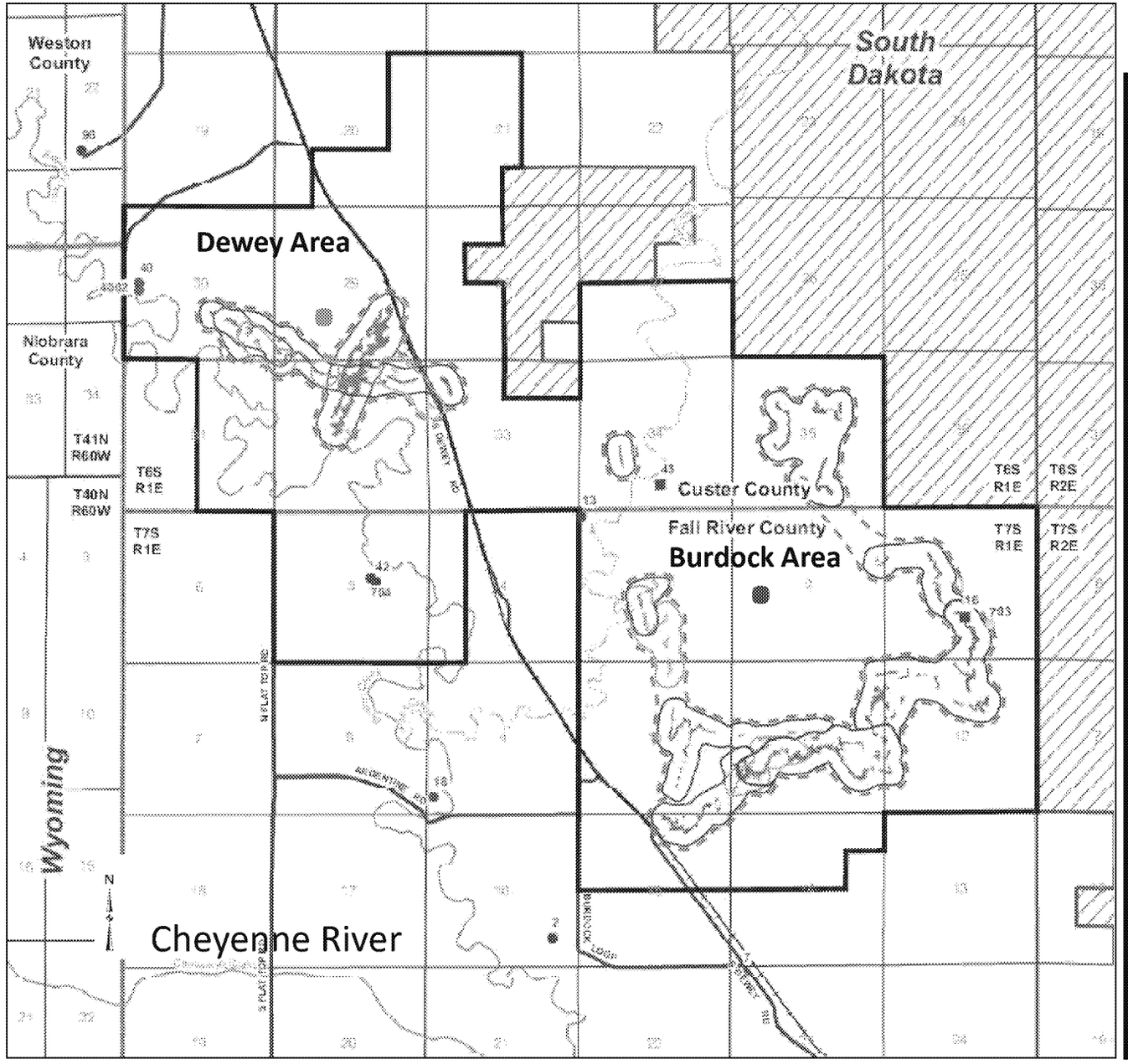
Play Video: In-SituRecoveryUranium.mp4



Dewey-Burdock Location Map



Dewey-Burdock Proposed Injection Well Locations



Explanation

Project Boundary

Proposed Aquifer Exemption Boundary

Class III Wellfields

Ore Deposits

- Lower Fall River
- Upper Chilson
- Middle/Lower Chilson

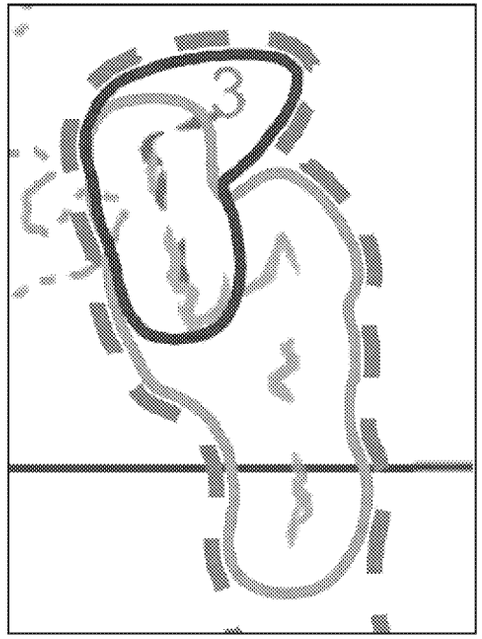
Monitoring Well Rings

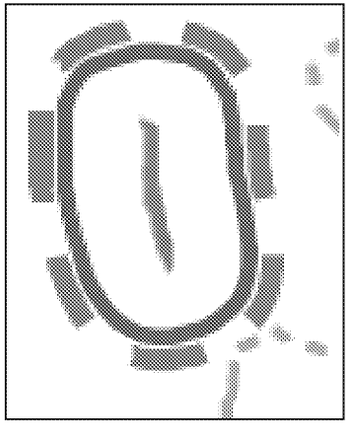
- Lower Fall River
- Upper Chilson
- Middle/Lower Chilson

Class V Deep Wells

- Deep Injection Well #1
- Deep Injection Well #2

Horizontal and Vertical Views of Ore Deposits





Legend

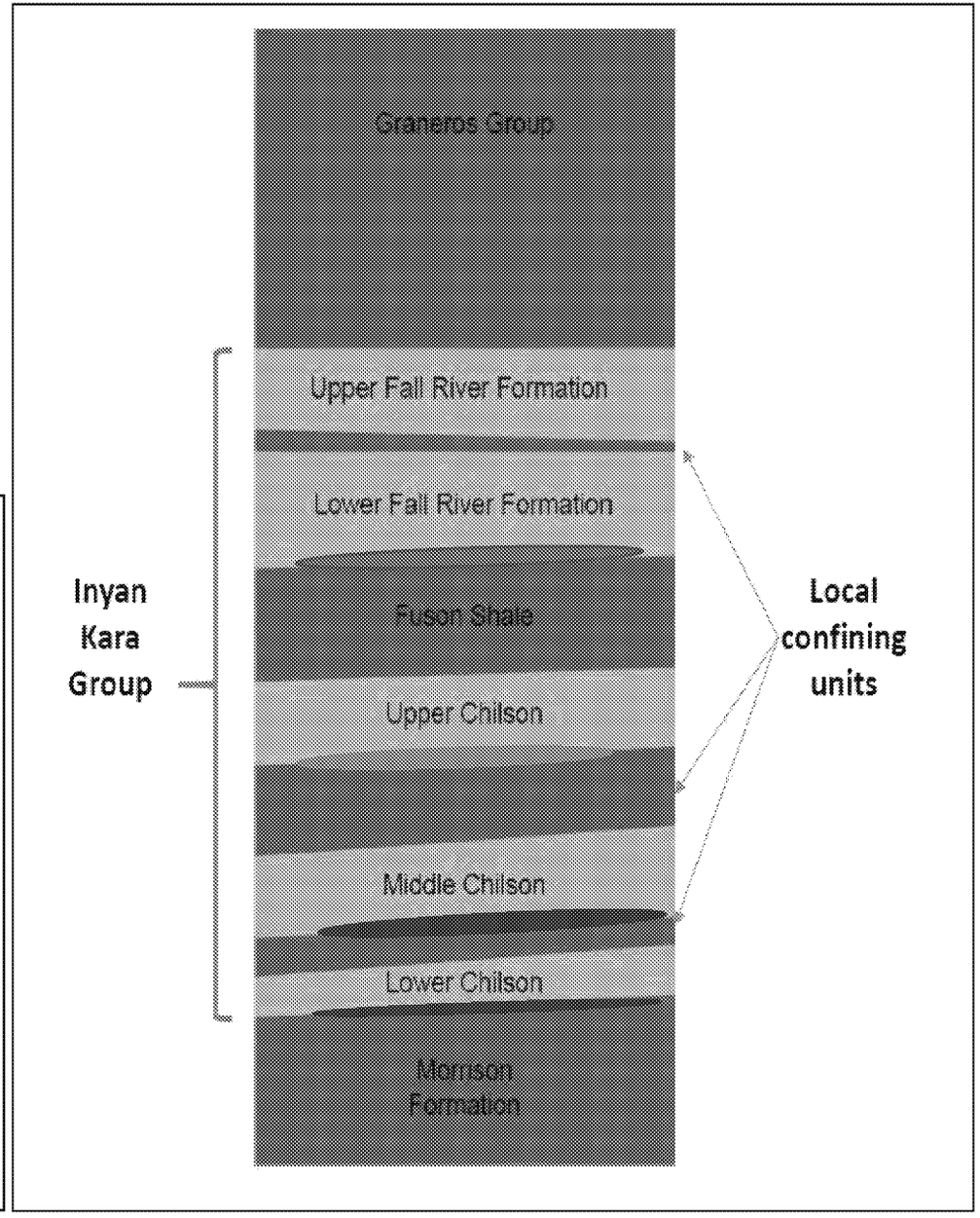
- Project Boundary
- Proposed Aquifer Exemption Boundary

Ore Deposits

- Lower Fall River
- Upper Chilson
- Middle/Lower Chilson

Perimeter Monitoring Well Ring Locations

- Lower Fall River
- Upper Chilson
- Middle/Lower Chilson



§ 146.32 Class III Well Construction requirements

(a) Casing and Cement

- Purpose: to prevent the migration of fluids into or between underground sources of drinking water.
- Designed for the life expectancy of the well
- For developing permit requirements, the following factors shall be considered:

(1) Depth to the injection zone;

(2) Injection pressure, external pressure, internal pressure, axial loading, etc.;

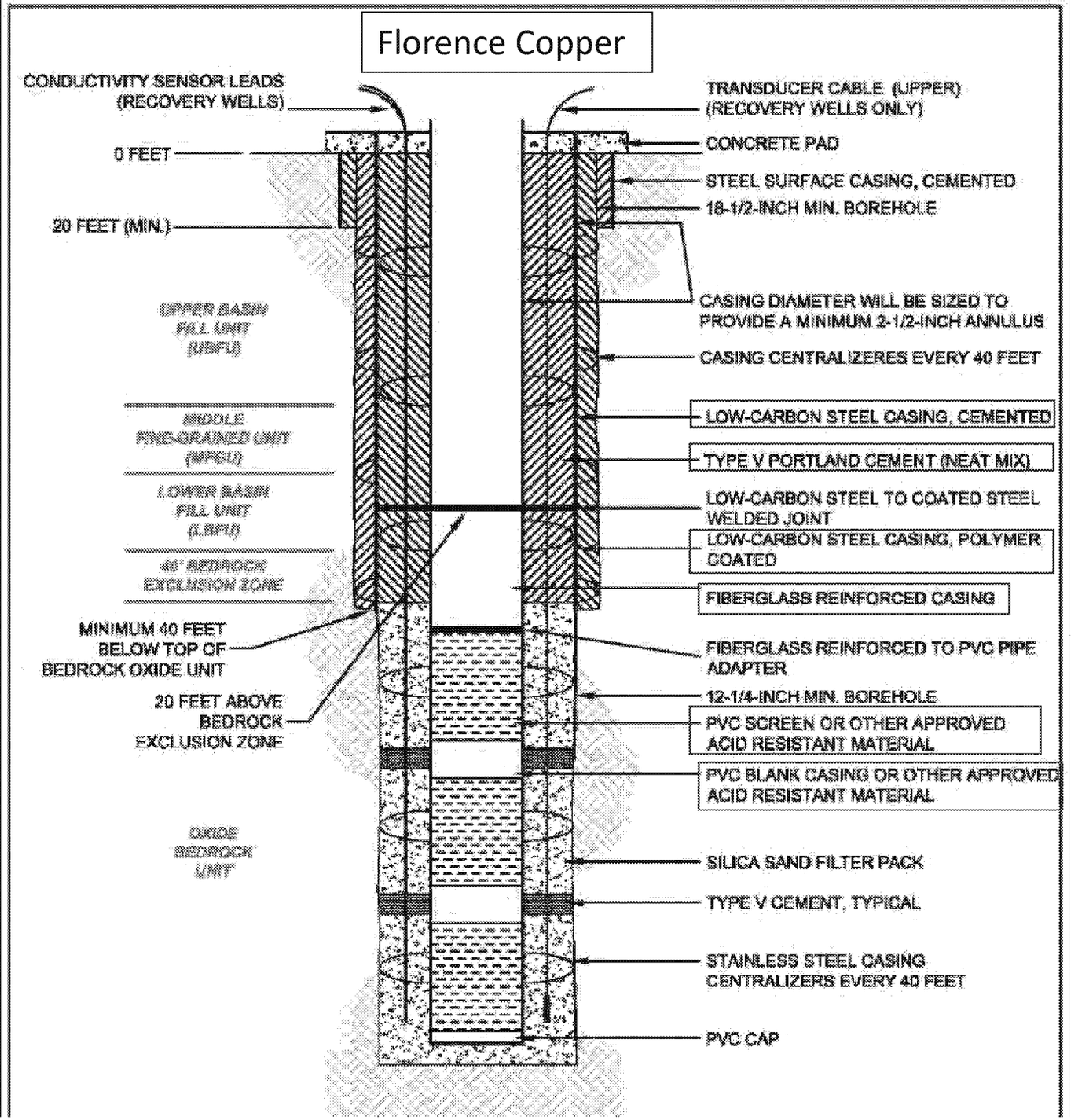
(3) Hole size;

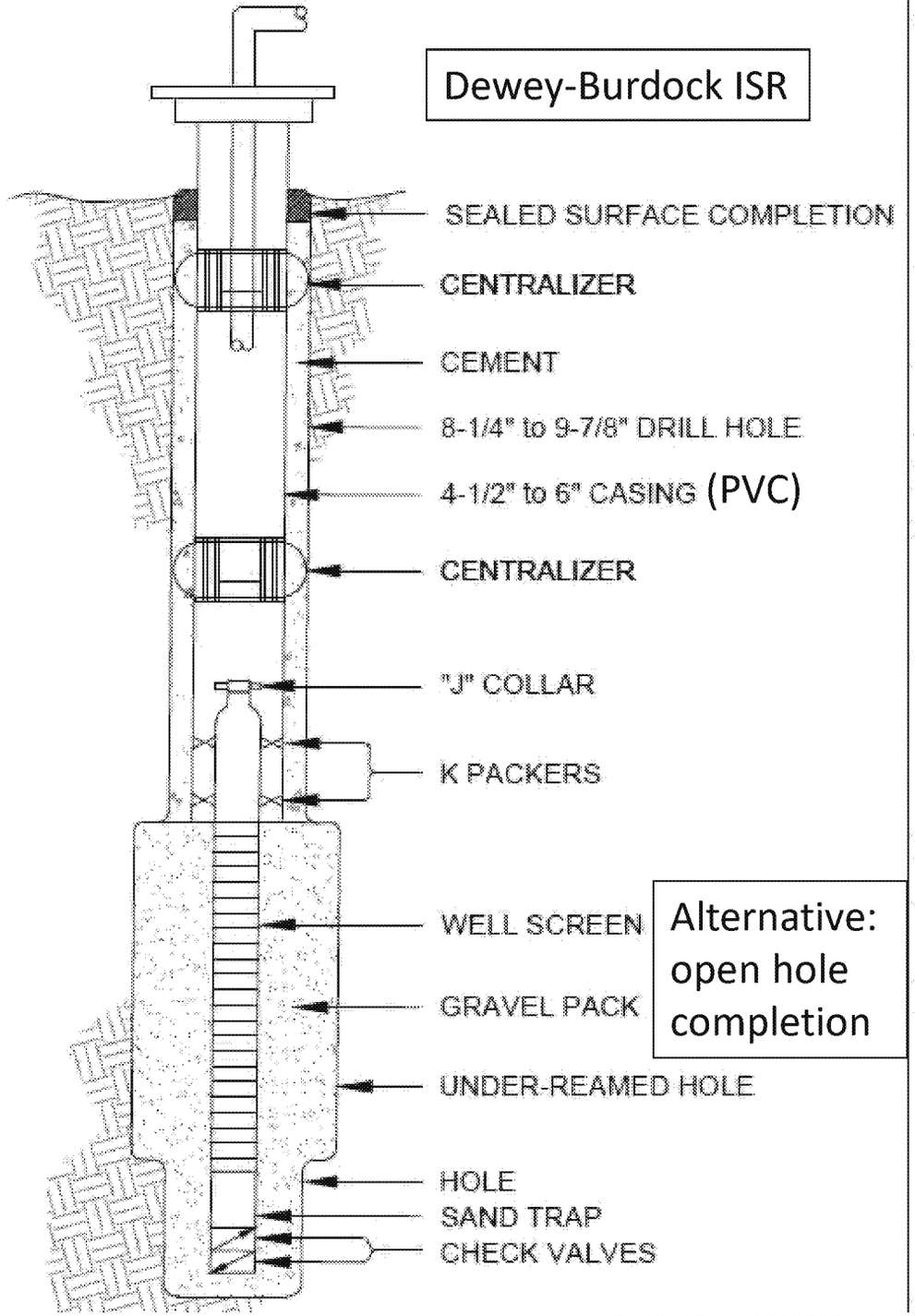
(4) Size and grade of all casing strings (wall thickness, diameter, nominal weight, length, joint specification, and construction material);

(5) Corrosiveness of injected fluids and formation fluids;

(6) Lithology of injection and confining zones; and

(7) Type and grade of cement


Florence Copper
CONDUCTIVITY SENSOR LEADS (RECOVERY WELLS)
TRANSDUCER CABLE (UPPER) (RECOVERY WELLS ONLY)
0 FEET
CONCRETE PAD
STEEL SURFACE CASING, CEMENTED
18-1/2-INCH MIN. BOREHOLE
20 FEET (MIN.)
UPPER BASIN FILL UNIT (UBFU)
CASING DIAMETER WILL BE SIZED TO PROVIDE A MINIMUM 2-1/2-INCH ANNULUS
CASING CENTRALIZERES EVERY 40 FEET
MIDDLE FINE-GRAINED UNIT (MFGU)
LOW-CARBON STEEL CASING, CEMENTED
TYPE V PORTLAND CEMENT (NEAT MIX)
LOWER BASIN FILL UNIT (LBFU)
LOW-CARBON STEEL TO COATED STEEL WELDED JOINT
40' BEDROCK EXCLUSION ZONE
LOW-CARBON STEEL CASING, POLYMER COATED
FIBERGLASS REINFORCED CASING
MINIMUM 40 FEET BELOW TOP OF BEDROCK OXIDE UNIT
FIBERGLASS REINFORCED TO PVC PIPE ADAPTER
12-1/4-INCH MIN. BOREHOLE
20 FEET ABOVE BEDROCK EXCLUSION ZONE
PVC SCREEN OR OTHER APPROVED ACID RESISTANT MATERIAL
PVC BLANK CASING OR OTHER APPROVED ACID RESISTANT MATERIAL
OXIDE BEDROCK UNIT
SILICA SAND FILTER PACK
TYPE V CEMENT, TYPICAL
STAINLESS STEEL CASING CENTRALIZERS EVERY 40 FEET
PVC CAP


Dewey-Burdock ISR
SEALED SURFACE COMPLETION
CENTRALIZER
CEMENT
8-1/4" to 9-7/8" DRILL HOLE
4-1/2" to 6" CASING (PVC)
CENTRALIZER
"J" COLLAR
K PACKERS
WELL SCREEN
GRAVEL PACK
UNDER-REAMED HOLE
HOLE
SAND TRAP
CHECK VALVES
Alternative: open hole completion

40 CFR Part 147 Subpart QQ—South Dakota

§147.2100 State-administered program—Class II wells.

§147.2101 EPA-administered program—
Class I, III, IV and V wells and all wells on Indian lands.

§147.2102 Aquifer exemptions.

§147.2103 Existing Class II enhanced recovery and hydrocarbon storage wells authorized by rule.

§147.2104 Requirements for all wells.

(b) The owner or operator of a new injection well cased with plastic (PVC, ABS, or others) casings shall:

(1) Not construct a well deeper than 500 feet;

(2) Use cement and additives compatible with such casing material; and

(3) Cement the annular space above the injection internal from the bottom of the blank casing to the surface.

§ 146.32 Class III Well Construction requirements

(e) Where injection is into an Underground Source of Drinking Water…

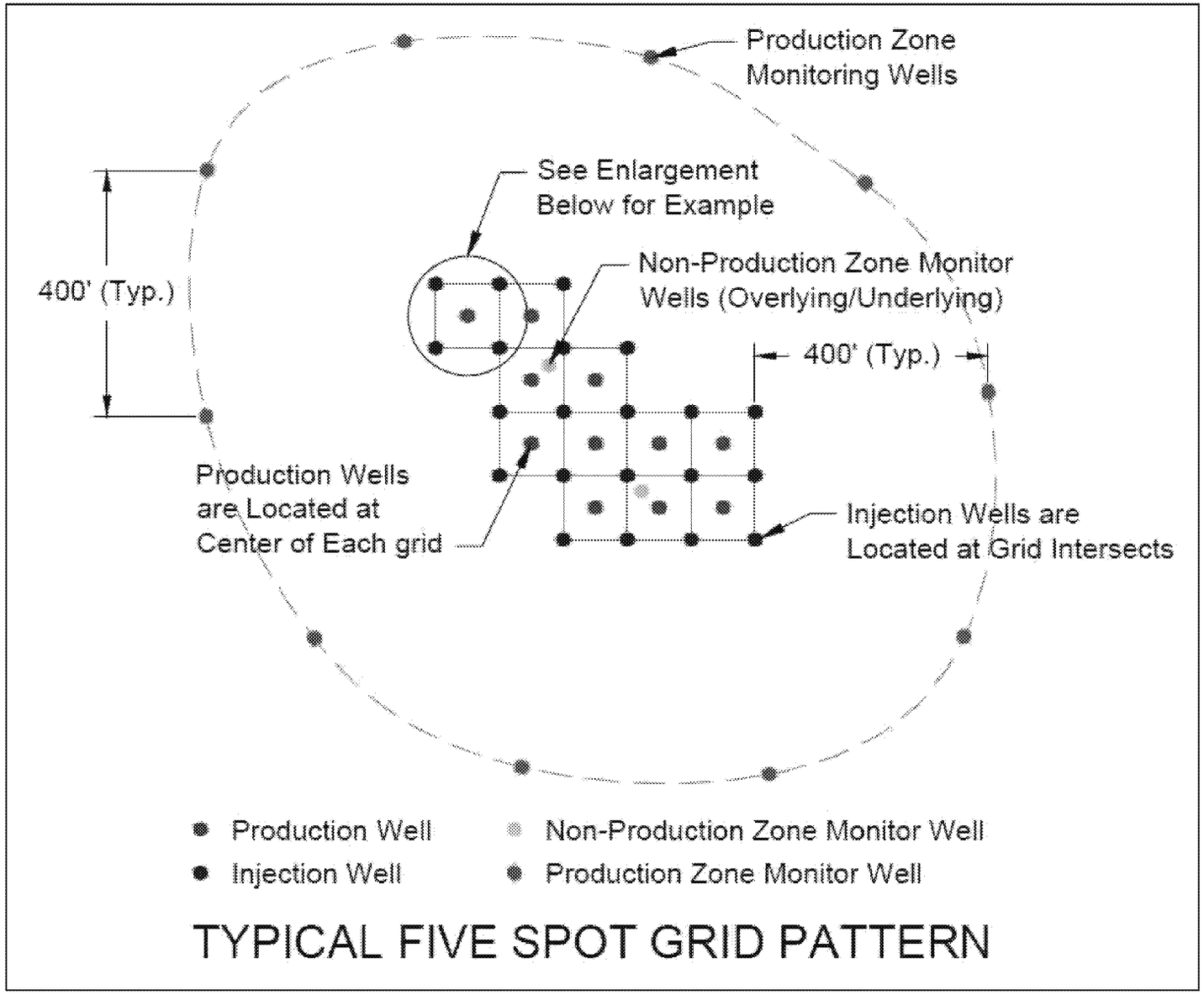
monitoring wells

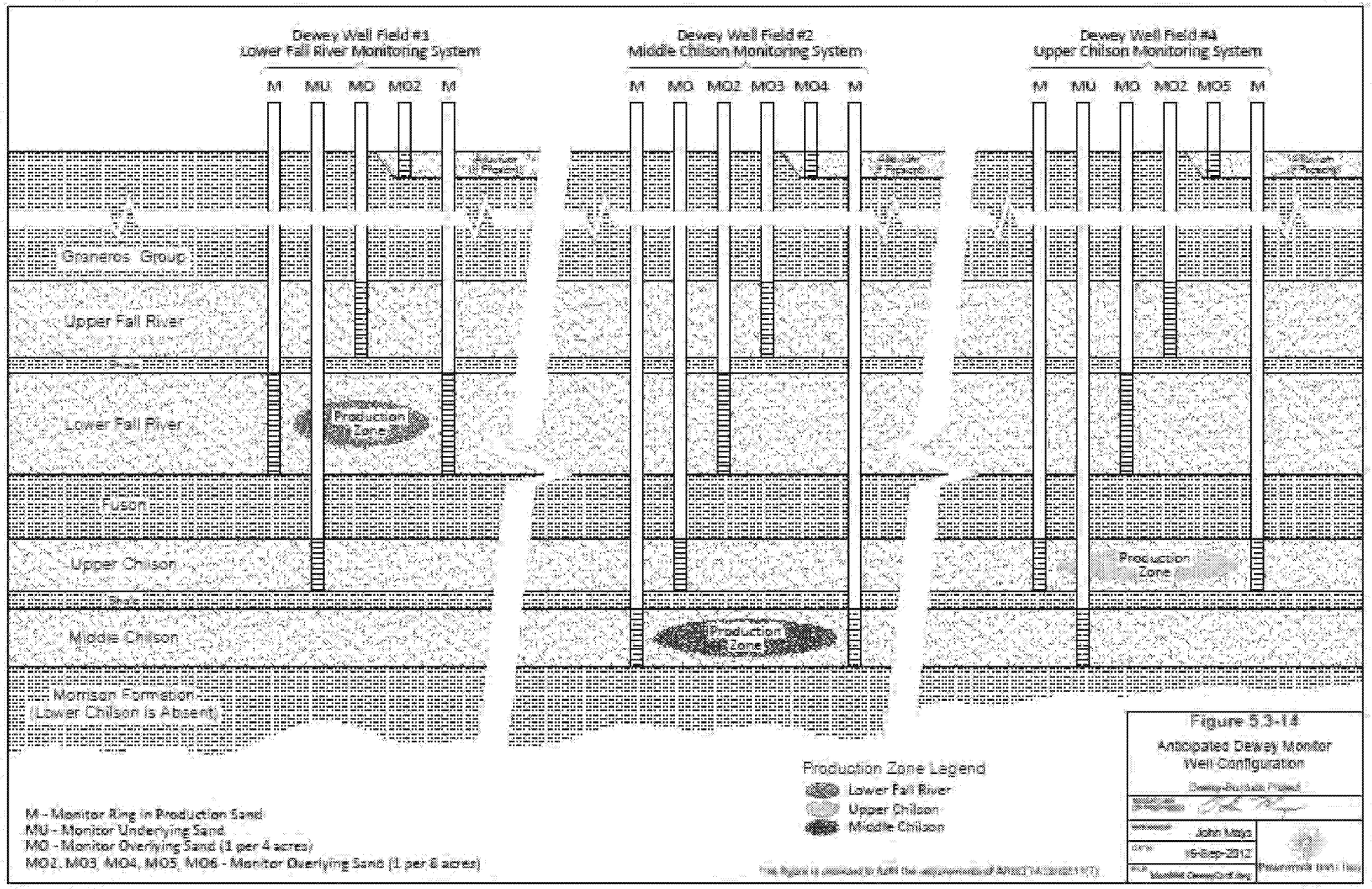
- In the injection zone and
- In any USDWs above the injection zone which could be affected by the mining operation.

Monitoring well must located in such a fashion as to detect any **excursion of injection fluids**, process by-products, or formation fluids outside the mining area or zone.

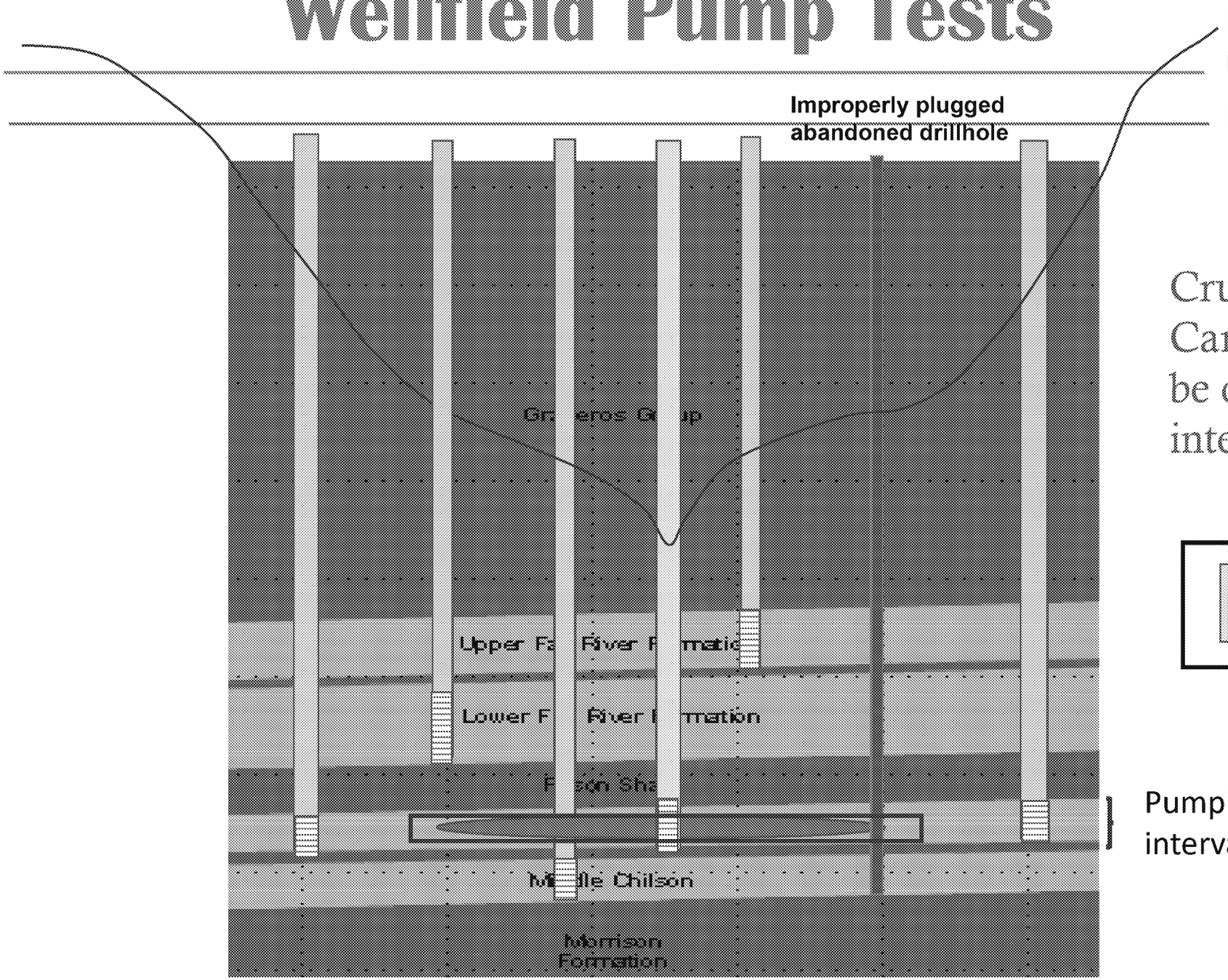
If the operation may be affected by **subsidence** or **catastrophic collapse** the monitoring wells shall be located so that they will not be physically affected.

Example Class III Uranium ISR Wellfield




Dewey Well Field #1
Lower Fall River Monitoring System
M MU MO MO2 M
Dewey Well Field #2
Middle Chilson Monitoring System
M MO MO2 MO3 MO4 M
Dewey Well Field #4
Upper Chilson Monitoring System
M MU MO MO2 MO5 M
Graneros Group
Upper Fall River
Shale
Lower Fall River
Production Zone
Fuson
Upper Chilson
Production Zone
Shale
Middle Chilson
Production Zone
Morrison Formation
(Lower Chilson is Absent)
M - Monitor Ring in Production Sand
MU - Monitor Underlying Sand
MO - Monitor Overlying Sand (1 per 4 acres)
MO2, MO3, MO4, MO5, MO6 - Monitor Overlying Sand (1 per 8 acres)
Production Zone Legend
Lower Fall River
Upper Chilson
Middle Chilson
Figure 5.3-14
Anticipated Dewey Monitor Well Configuration
John Mays
6-Sep-2012

Wellfield Pump Tests

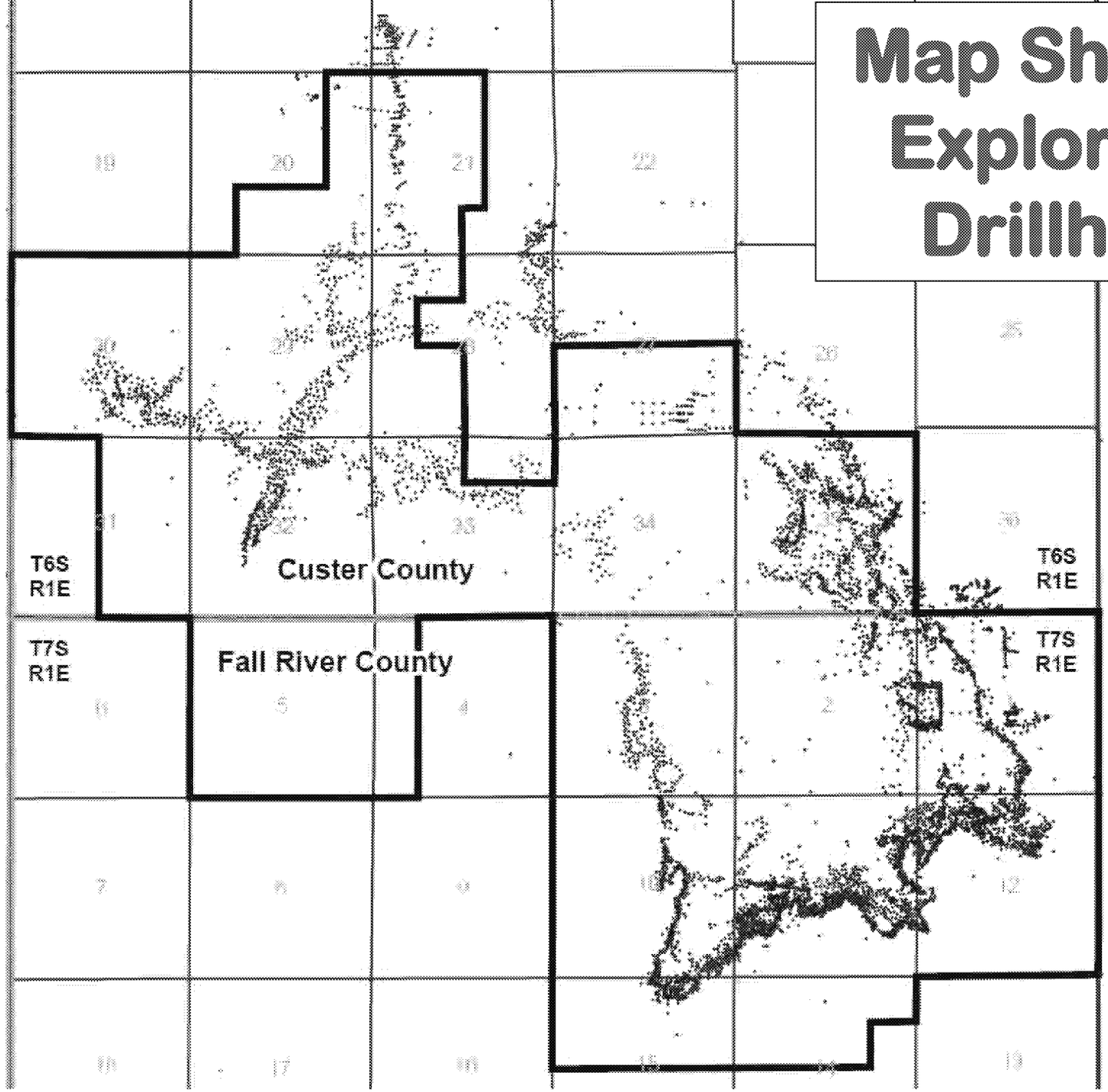


Crucial Question for Pump Test: Can the uranium-bearing fluids be contained within the injection interval?

Pumping well

Monitoring well

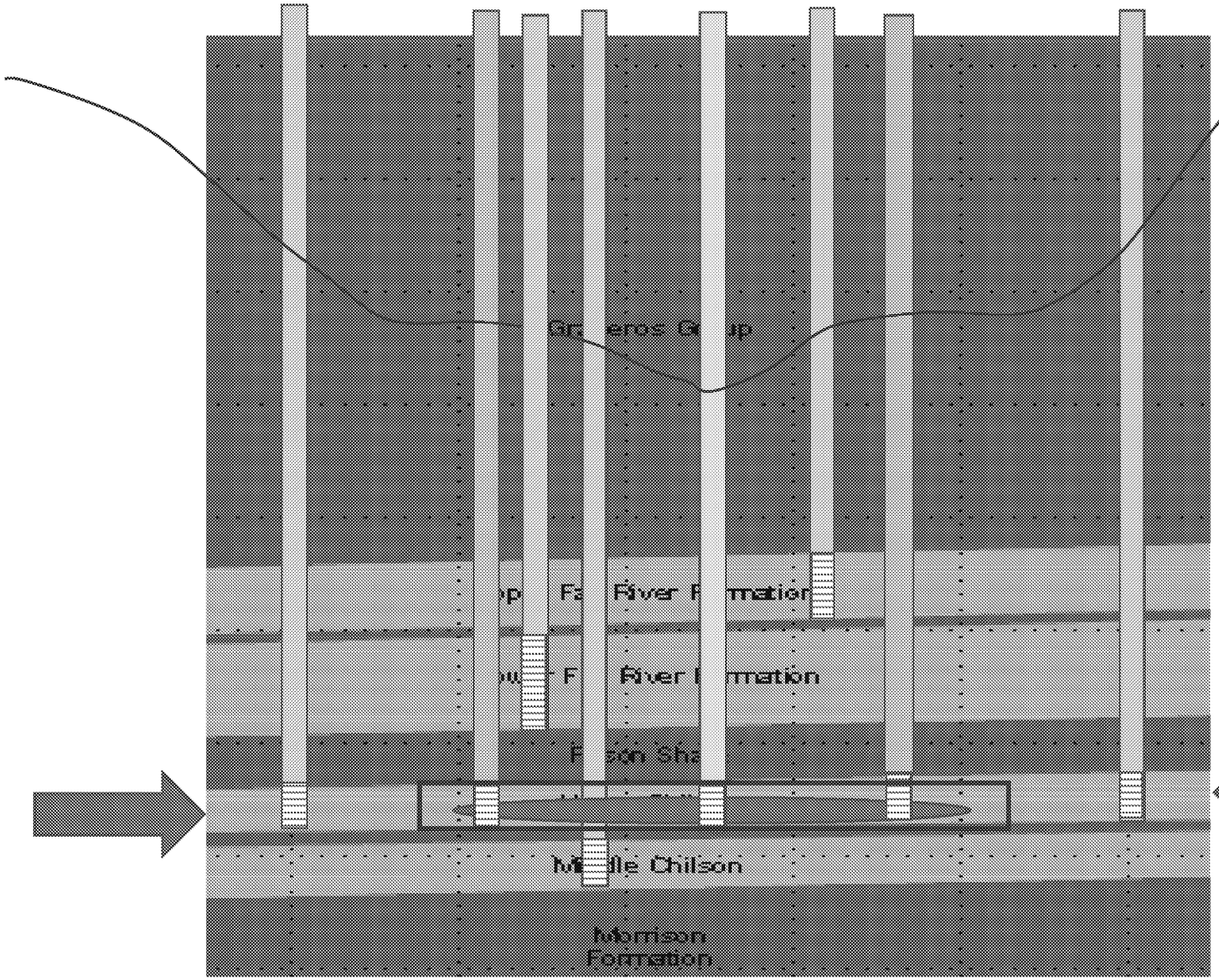
Map Showing Exploration Drillholes

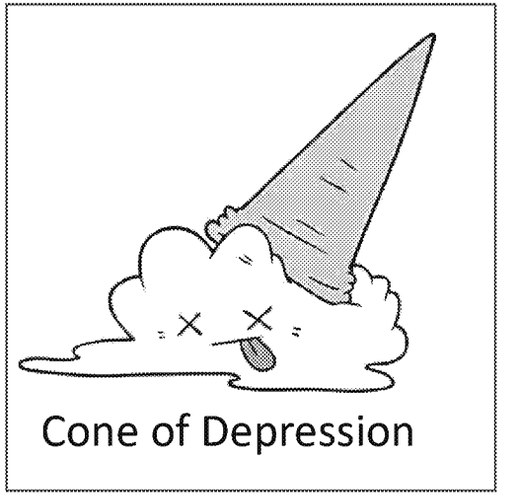


Hydraulic Control of Injected Fluids

Less In than Out

Volume of injected fluids is less than the volume of produced fluids





Monitoring Well

Production Well

Injection Well

Injection interval groundwater flow toward wellfield

Wellfield injection interval

§ 146.33 Operating, monitoring, & reporting requirements.

(b) *Monitoring requirements.* Monitoring requirements shall, at a minimum, specify:

(1) Monitoring of injected fluids

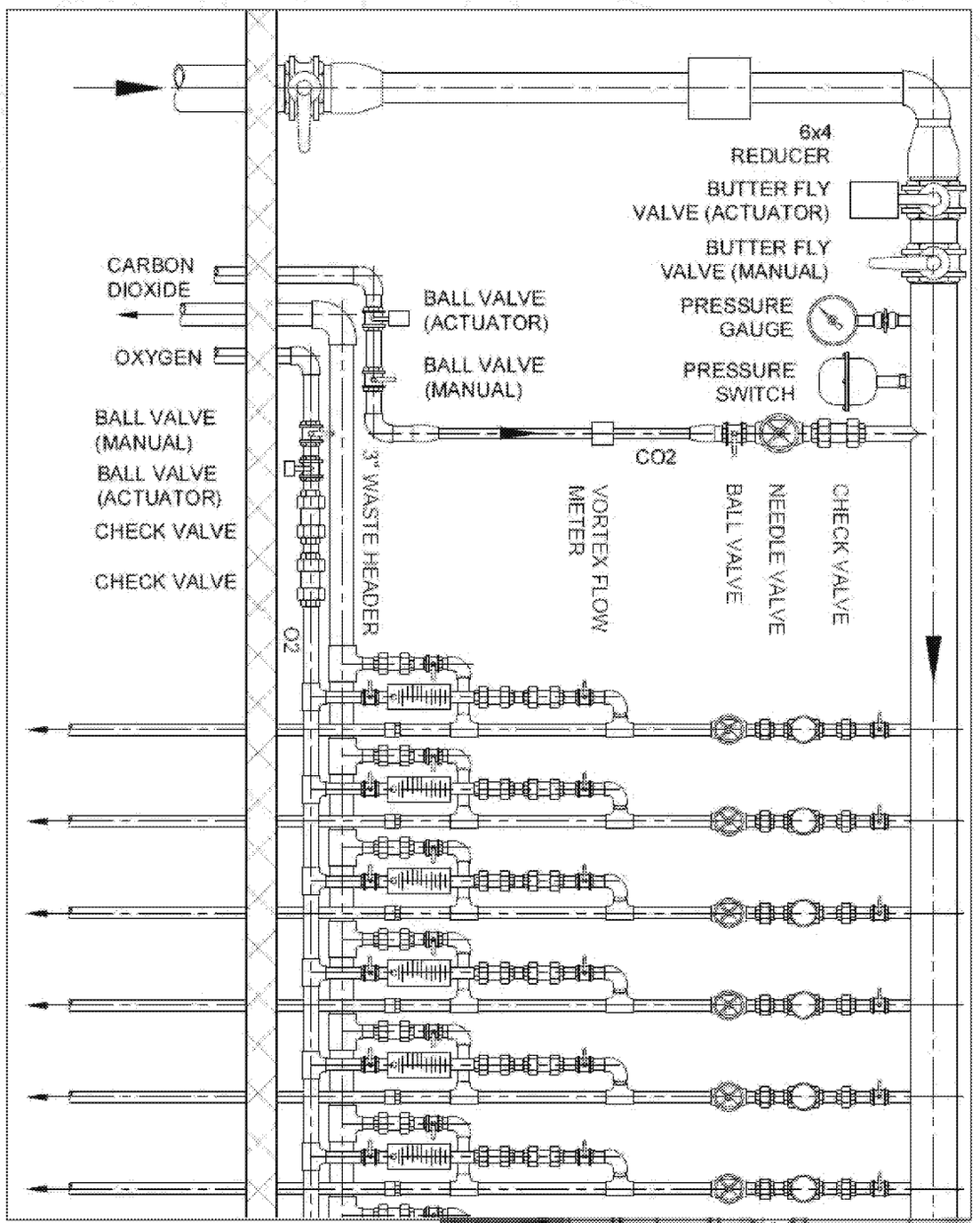
(2) Monitoring of injection pressure and either flow rate or volume semi-monthly, or metering and daily recording of injected and produced fluid volumes as appropriate.

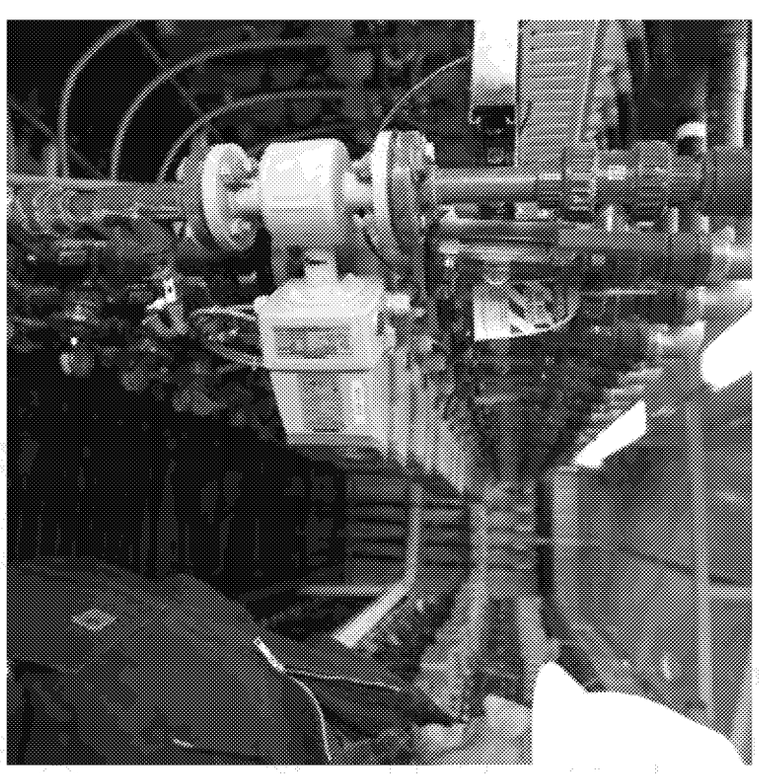
(3) Demonstration of mechanical integrity pursuant to §146.08 at least once every five years during the life of the well.

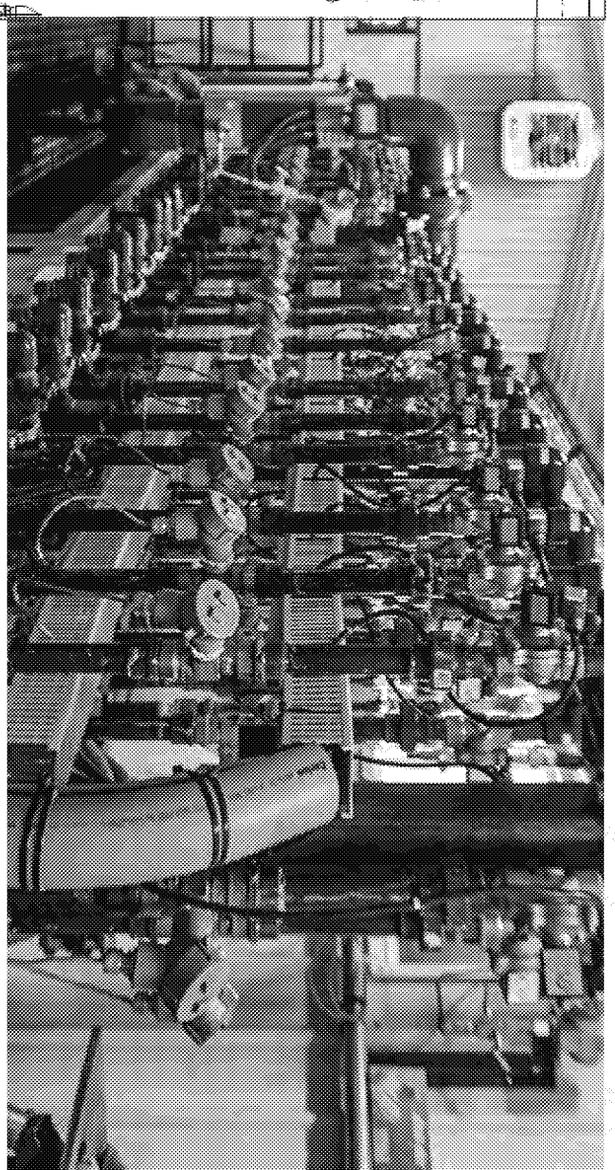
(4) Monitoring of the fluid level in the injection zone semi-monthly, where appropriate and monitoring of the parameters chosen to measure water quality in the monitoring wells required by §146.32(e), semi-monthly.

(5) Quarterly monitoring of wells required by §146.32(g). (over subsidence areas)

(6) All Class III wells may be monitored on a field or project basis rather than an individual well basis by manifold monitoring. Manifold monitoring may be used in cases of facilities consisting of more than one injection well, operating with a common manifold. Separate monitoring systems for each well are not required provided the owner/operator demonstrates that manifold monitoring is comparable to individual well monitoring.





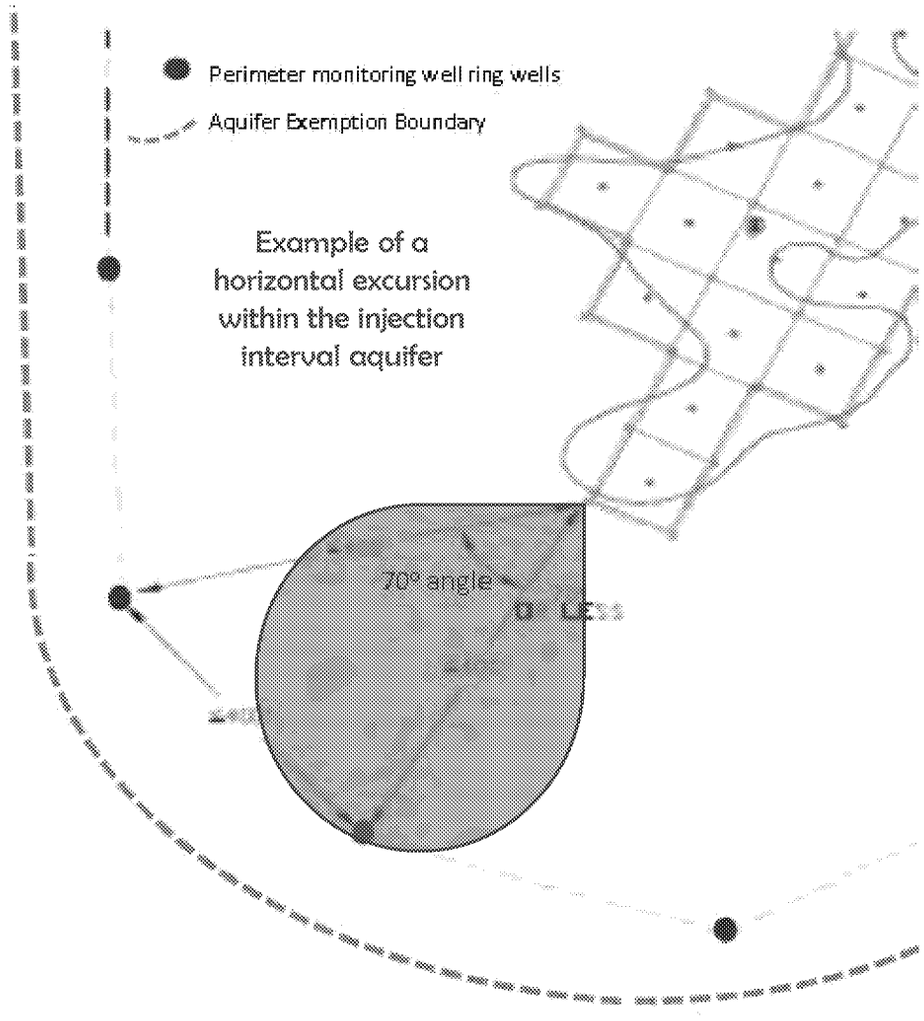


Excursion Monitoring

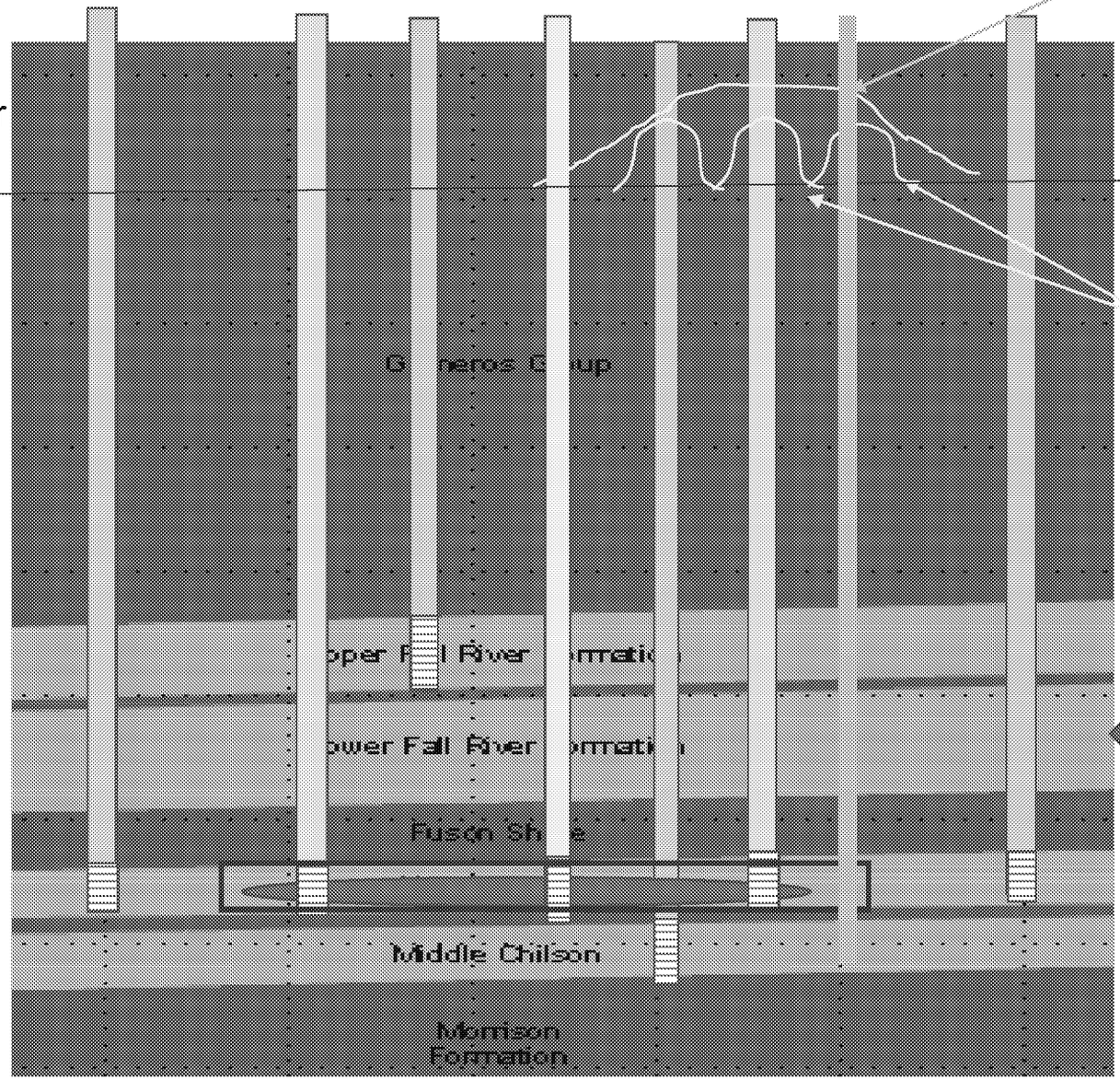
Excursion indicator parameters are more mobile constituents of the lixiviant that move faster through the injection interval aquifer than the other constituents. The proposed excursion indicators are alkalinity, conductivity and chloride.

When the excursion indicators move out of the wellfield injection interval area and are detected at a perimeter monitoring well, the event is called an "excursion."

If an excursion is detected at a perimeter monitoring well, the monitoring frequency of the impacted well is increased to every week until the excursion plume is removed.



Example of Vertical Excursion



Lower Fall River groundwater level

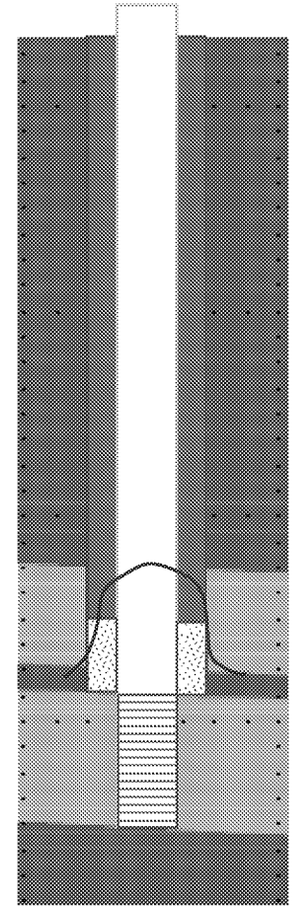
Improperly plugged historic exploration drillhole

Examples of vertical excursion across a confining zone into a non-injection interval aquifer

Injection interval groundwater flow toward wellfield

Injection interval groundwater flow toward wellfield

Well construction diagram



cement

well casing

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

Uranium recovery facilities must obtain a radioactive materials handling license.

The U.S. Nuclear Regulatory Commission (NRC) currently regulates operating uranium recovery facilities in New Mexico, Nebraska and South Dakota.

THE NRC does not directly regulate the active uranium recovery operations in Texas, Colorado, Wyoming, and Utah, as they are Agreement States.

Agreement states have entered into strict agreements with the NRC to exercise regulatory authority over this type of material.

Safe Wellfield Operation.

A. Verify that injection pressures are being maintained below casing and formation rupture pressures.

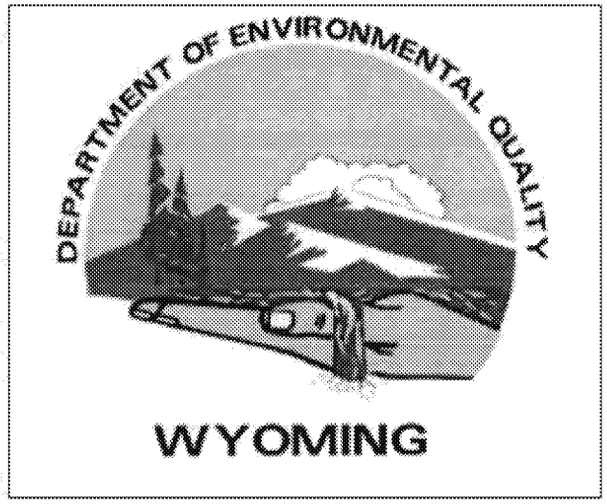
B. Verify that the licensee is appropriately evaluating well field injection and production rates and that the appropriate levels of bleed are being maintained in the wellfields to prevent excursions.

C. Verify that the correct monitor wells are being appropriately monitored for upper control limit values and that excursions are being reported to the Department as required in the license.

D. Verify that any ongoing excursions are being cleaned up, that the Department is being appropriately informed, that the excursions are being monitored, and that the licensee is following its excursion cleanup plan.

E. Verify that license conditions regarding integrity test schedules for injection and production wells are being met (e.g. one MIT per well per 5 years).

F. Observe well abandonment operations to ensure proper plugging and abandonment of wells.



Water Disposal

- There are Class I disposal wells onsite to inspect.
- Verify that the deep-well disposal operations conform to applicable permit conditions.

Ground Water Restoration.

A. Verify the status of wellfields (i.e., mining, inactive or restoration).

B. Verify that groundwater restoration activities conform to the groundwater restoration plan.

C. Verify that inward hydraulic gradient is being maintained inactive wellfields.

D. Verify that that excursion monitoring is active.

E. Verify that the groundwater data are being appropriately collected to determine if the groundwater is being restored.

F. Verify that groundwater samples are being appropriately collected during the restoration and post-restoration phases, to determine restoration success and post-restoration ground-water stability.

What are Class III Injection Wells?

40 CFR §144.6 Classification of wells

(c) *Class III.* Wells which inject for extraction of minerals including:

(1) Mining of sulfur by the Frasch process;

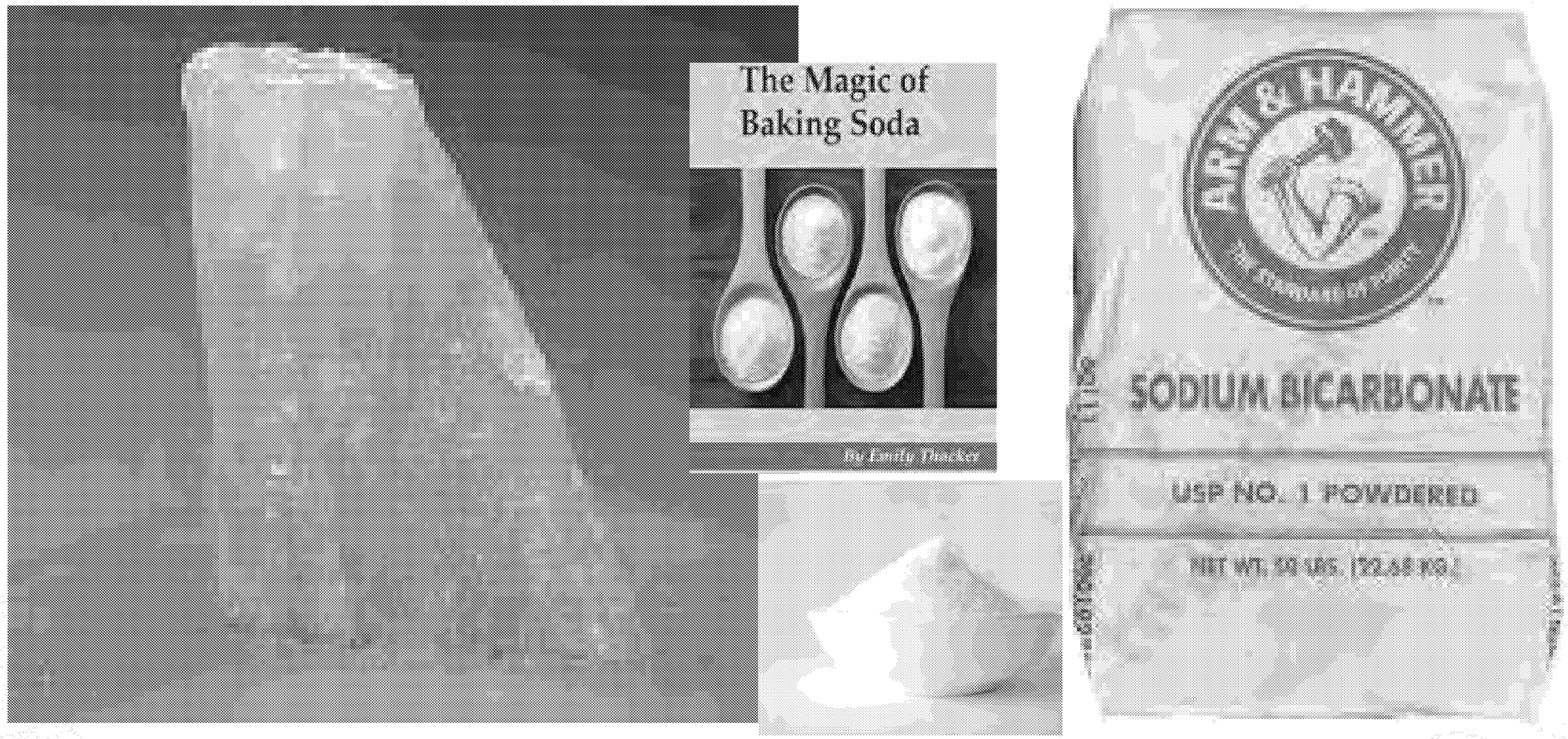
(2) In situ production of uranium or other metals;

(3) Solution mining of salts or potash.

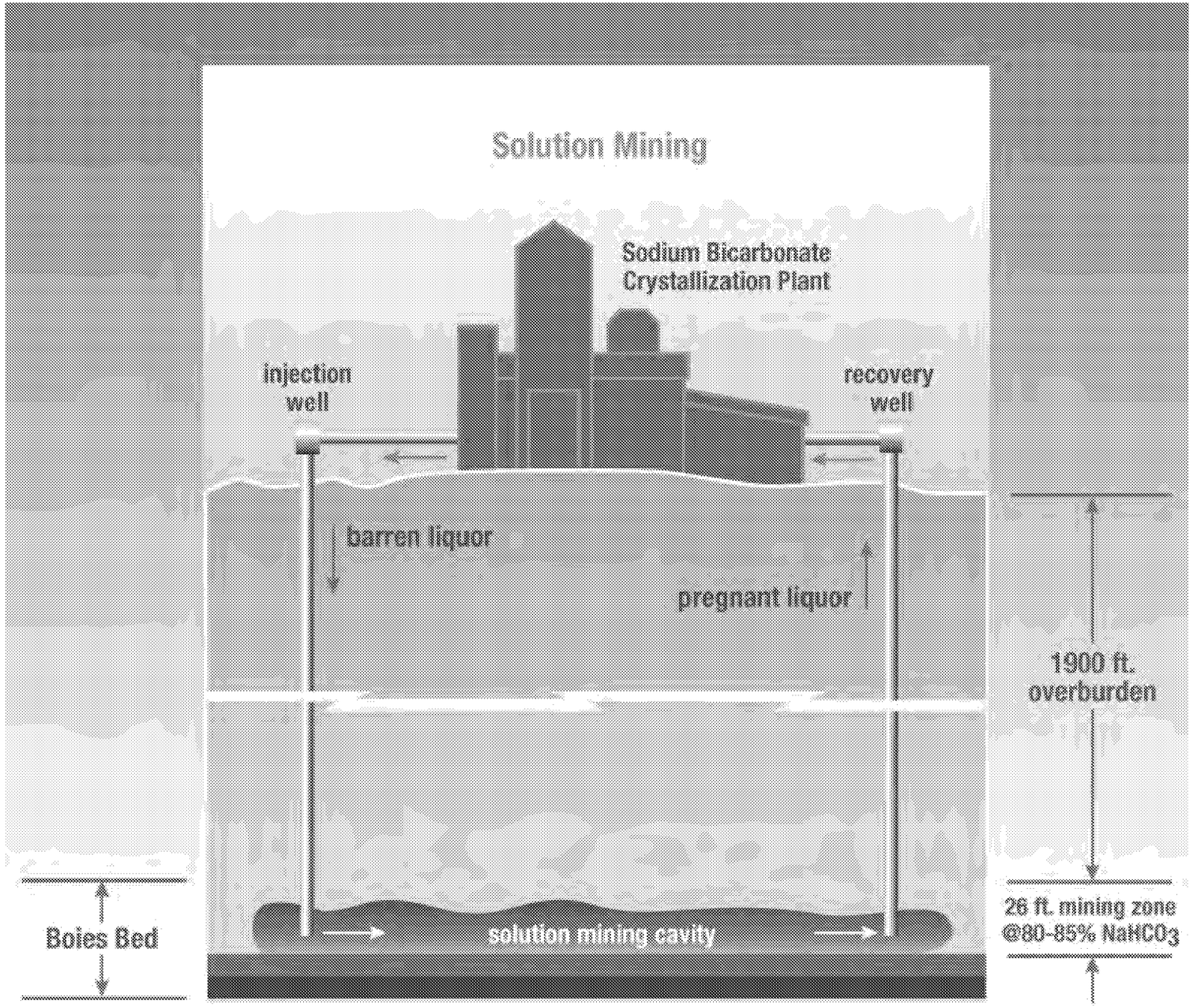
NATURAL SODA

Nahcolite Solution Mining

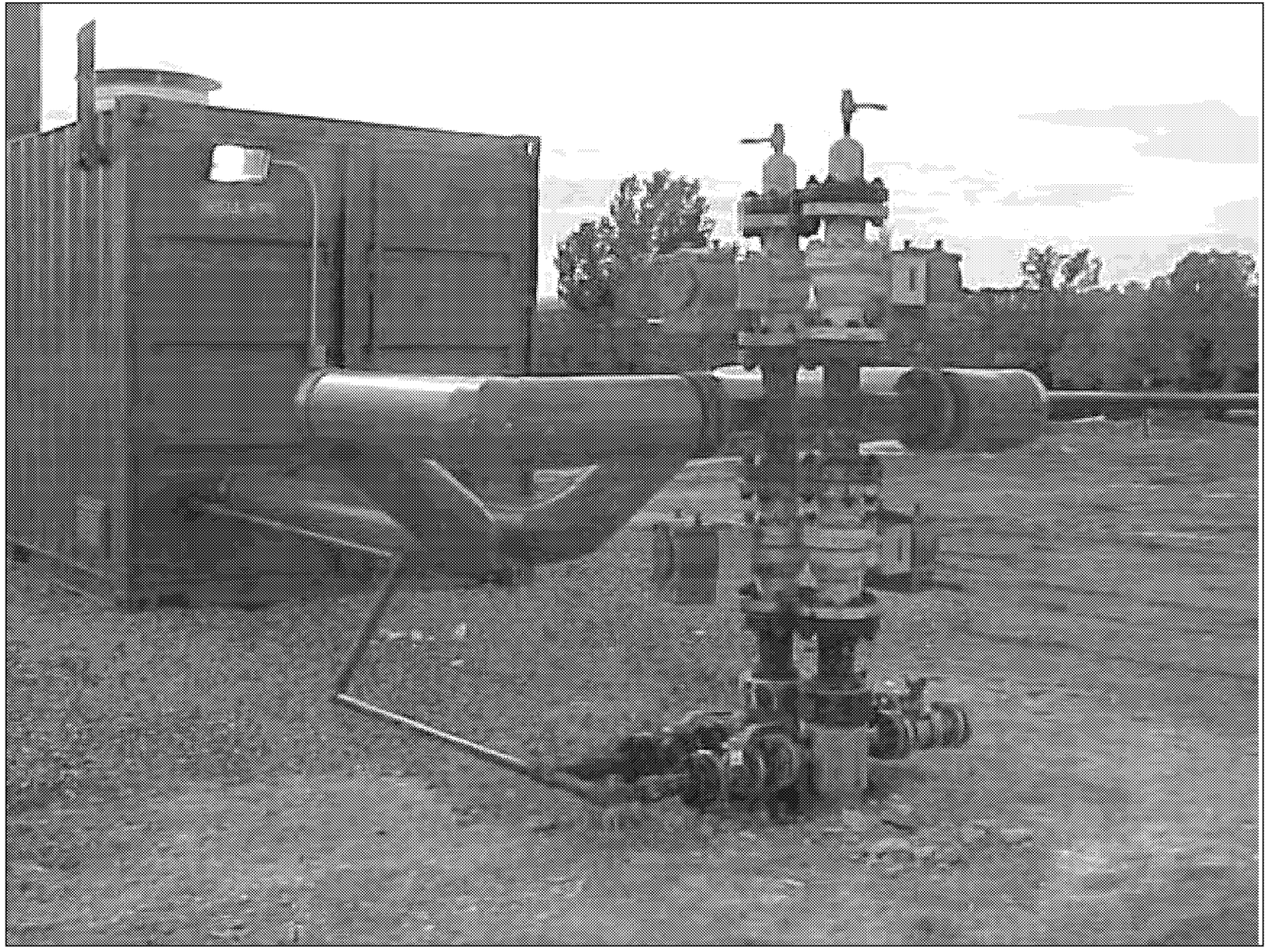
Play Video: NaturalSoda.mp4

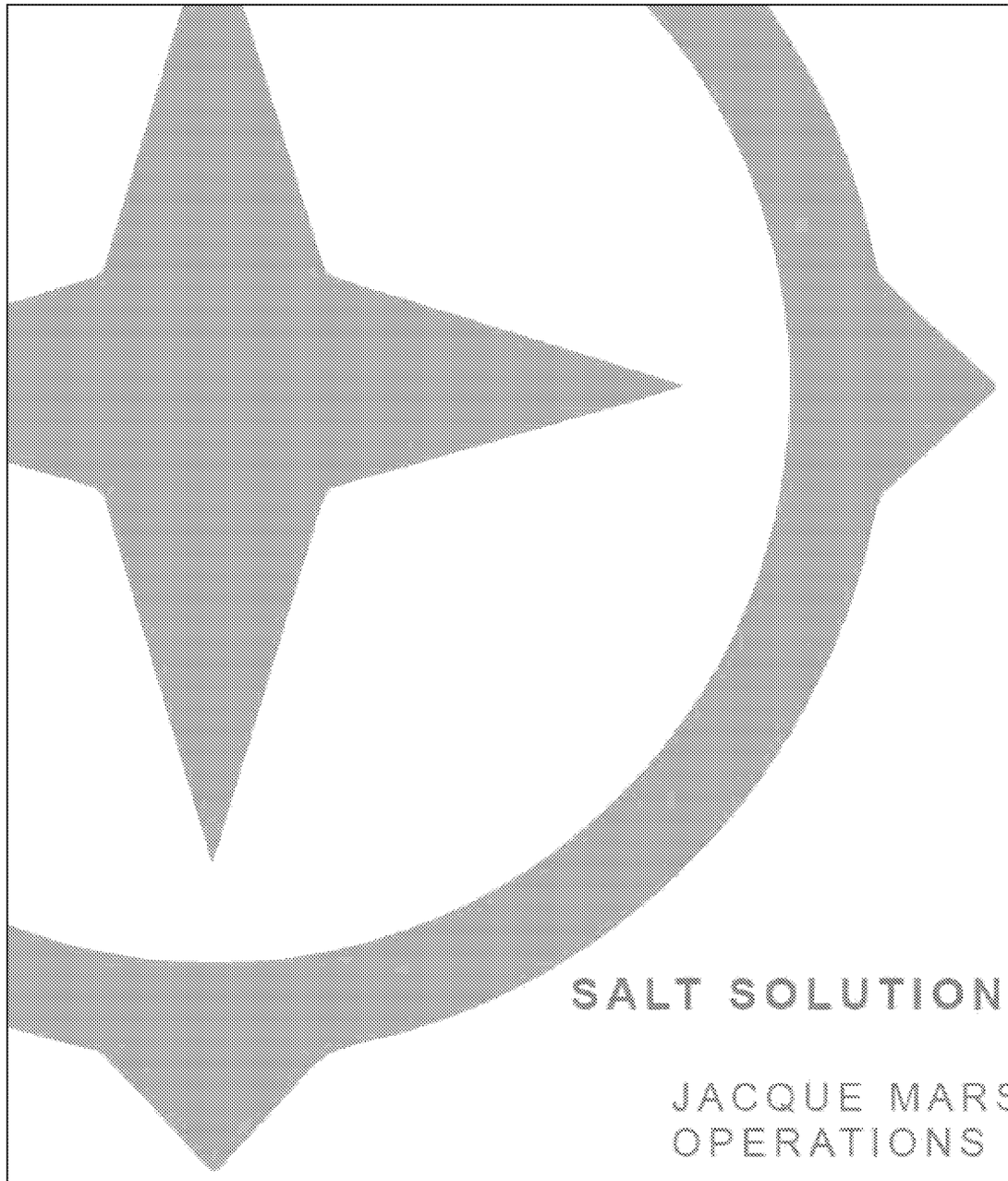


NATURAL SODA



Nahcolite Solution Mining Wellhead





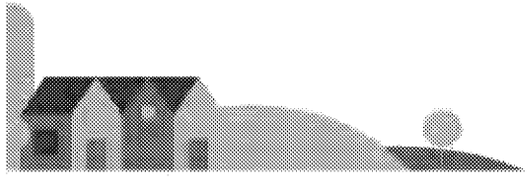
Compass Minerals

SALT SOLUTION MINING IN KANSAS

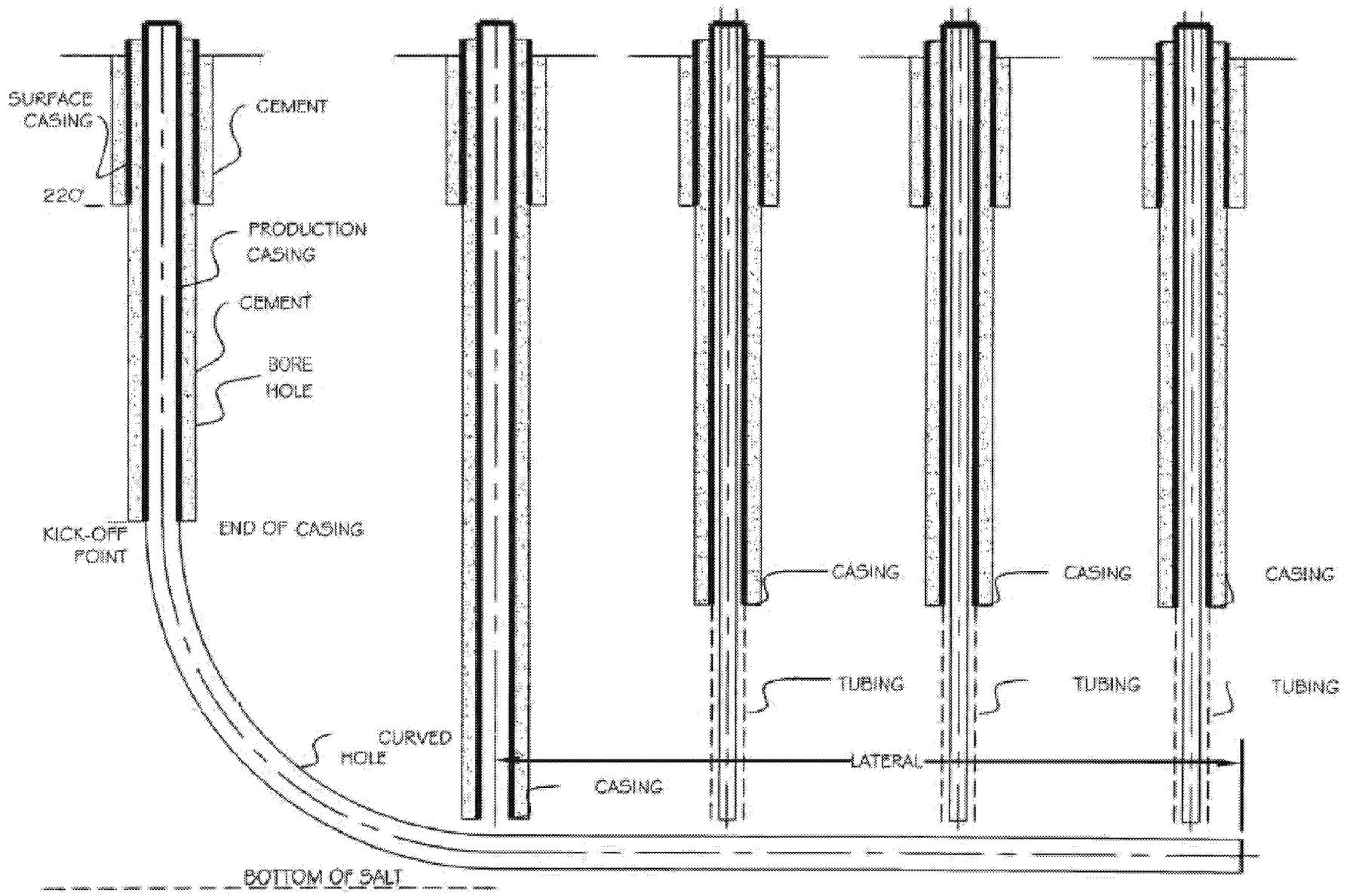
JACQUE MARSHALL
OPERATIONS SUPERINTENDENT

DEFINITIONS

- **Salt solution mining** – injecting unsaturated brine or fresh water through a well into a salt deposit resulting in saturated brine stream
- **Gallery system** – series of two of more salt mining wells that are artificially connected within the salt deposit layer
- **Horizontal or directional well** – directional borehole at the bottom of the salt layer used to connect the vertical wells
- **Vertical well** – drilled well used either for injection into or withdrawal from a salt deposit
- **Cavern** – void or space within salt deposit where salt has been mined by injection of water or unsaturated brine

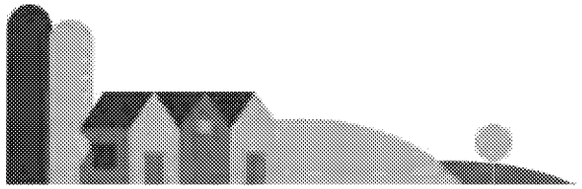


Typical Class III Horizontal Well Gallery



PHILOSOPHY

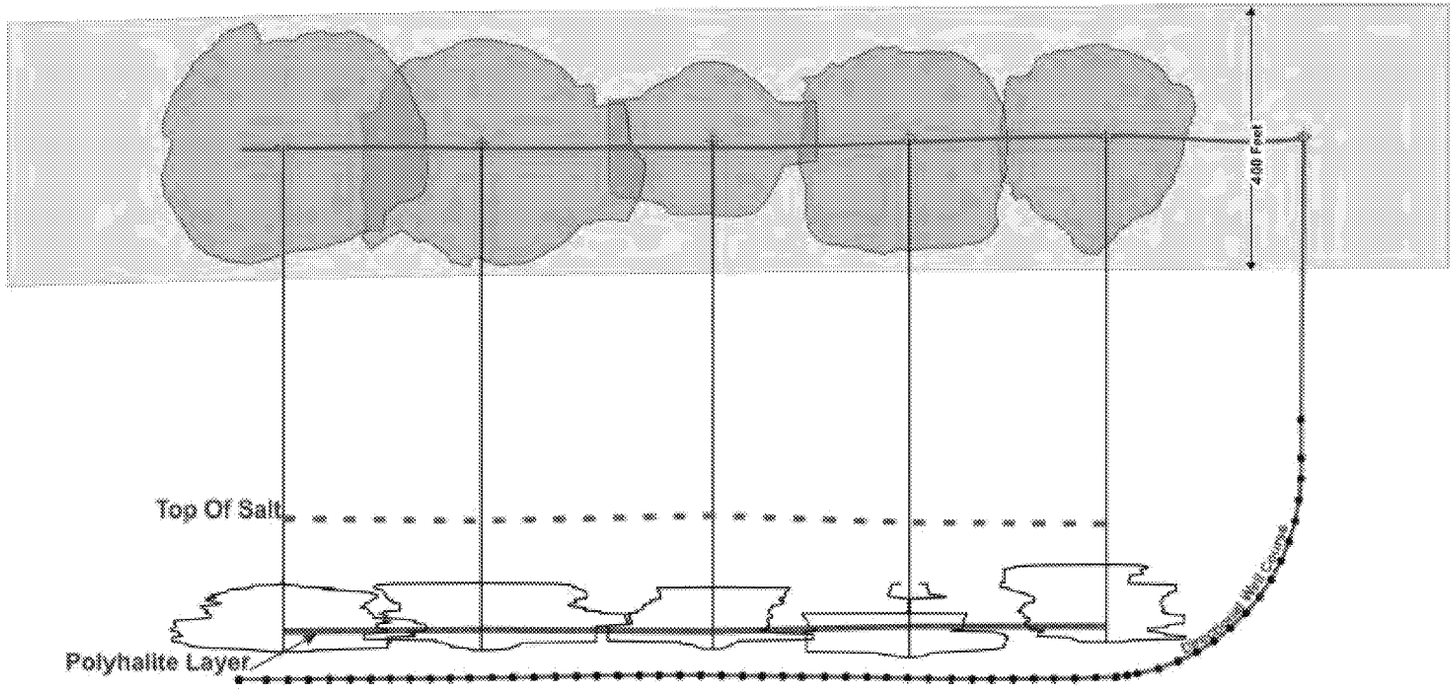
- Goal is to develop communication between caverns via horizontal well to recover as much salt as possible
- Inject a continuously recycled unsaturated brine stream from the evaporation process to produce saturated brine
- Vary injection and withdrawal rates and locations, and tubing depth settings to develop cavern
- Sonar and gamma technologies used to monitor cavern roof thickness and dimensions



PHILOSOPHY

Compass Minerals

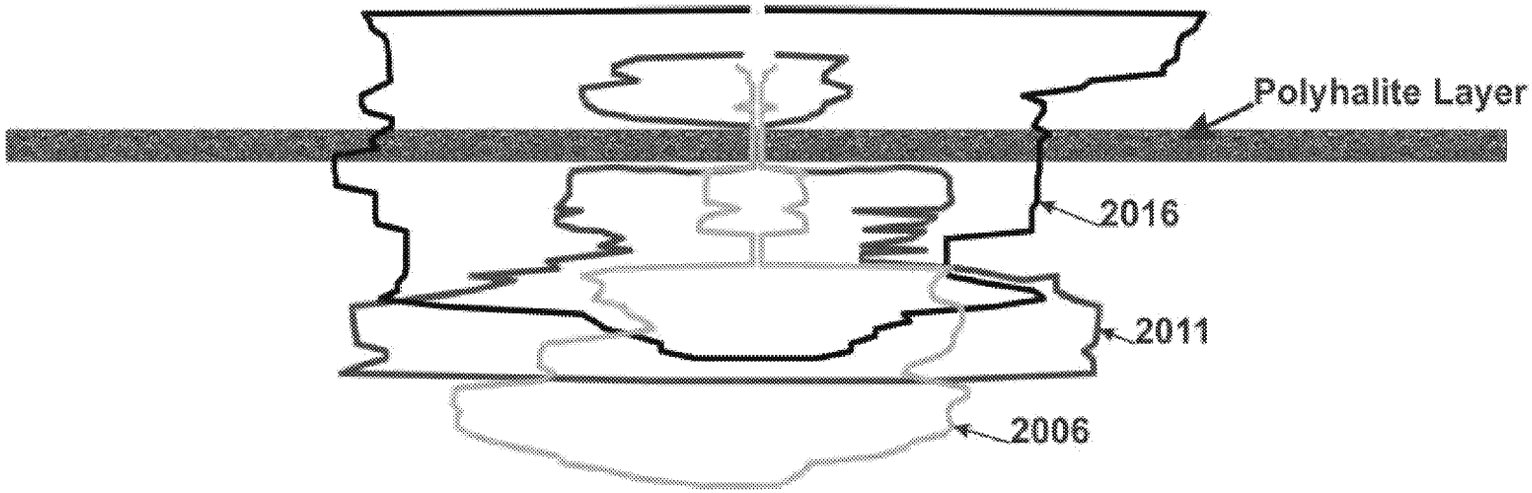
Top Down or Bird's Eye and Cross Sectional Views
Class III Horizontal Gallery



PHILOSOPHY

Compass Minerals

Cross Sectional View
Class III Well Development



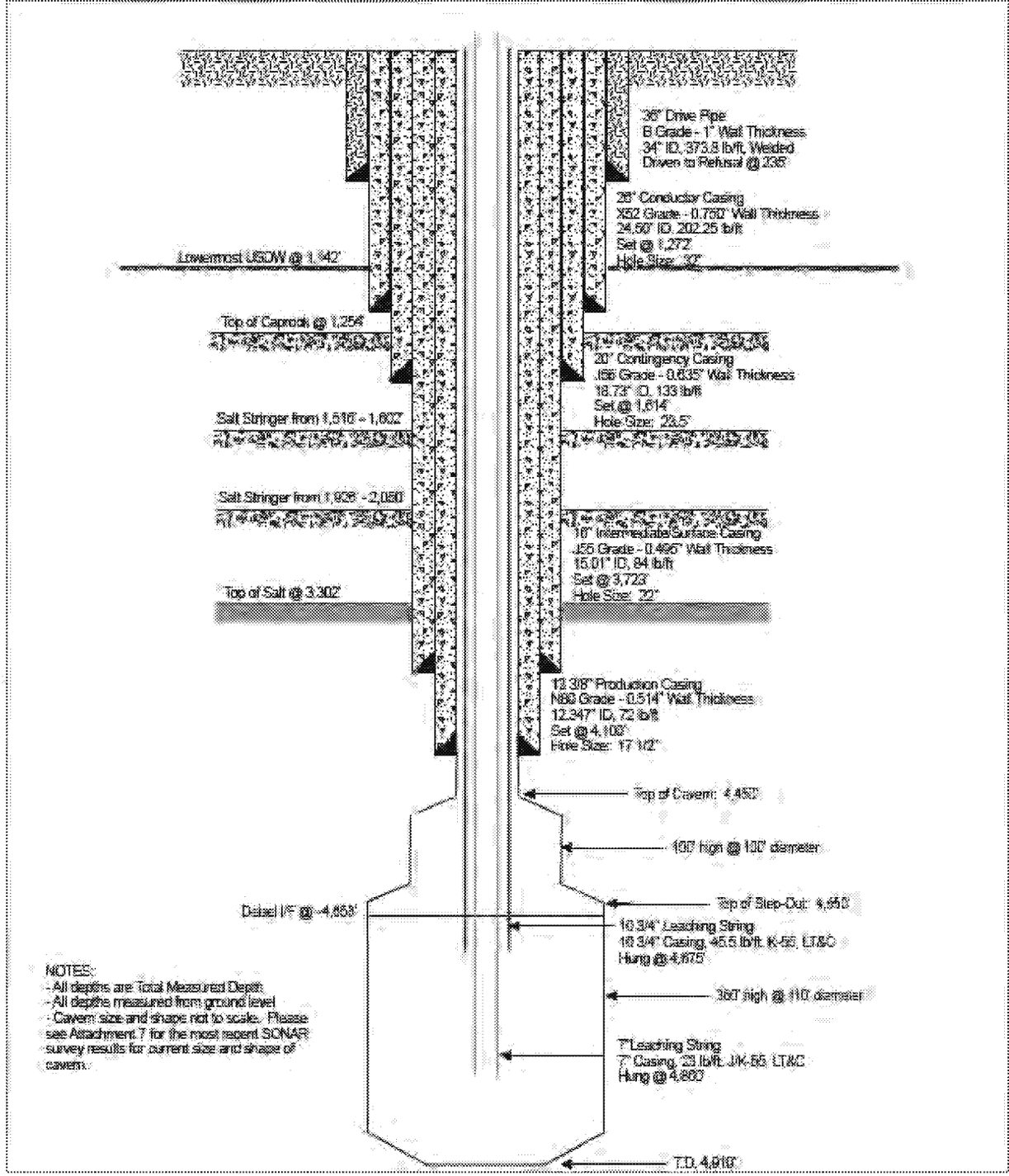
Louisiana Department of Natural Resources

Office of Conservation

Injection and Mining Division

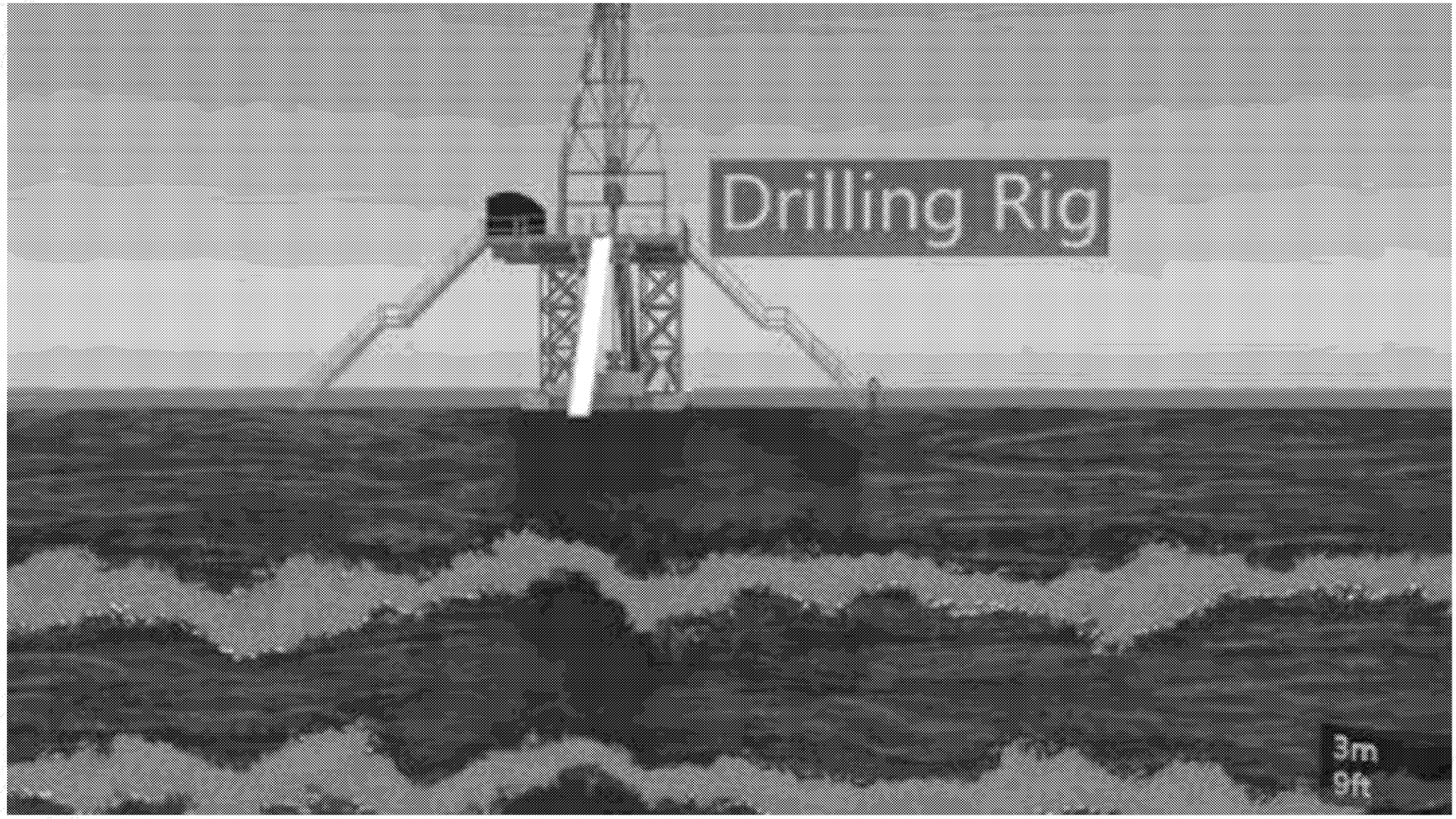
Class III wells inject fluids for extraction of minerals or energy. Currently, all permitted Class III wells in Louisiana are salt solution mining wells.

http://www.dnr.louisiana.gov/assets/OC/im_div/uic_workshop/6_PRES_CLASSI_CAVERNS.pptx



YANCOAL
兖煤加拿大资源有限公司

Play Video: PotashVideo.mp4



Pay Utilities Online

Water Quality Reports

Behind the Scenes of Water Treatment

Brine Well

Sewer

Brine Well

Brine Well Project

Brine, a water/salt mix, is used as a water softener to treat drinking water in the Hudson Water Treatment Plant and is used to treat road surfaces in icy weather. In February 2019, City Council authorized the construction of a brine well to reduce the money spent each year on salt to regenerate the water softeners at the water treatment plant.

What is a brine well?

With a salt-solution mining well, the City of Hudson will be able

What is a brine well?

With a salt-solution mining well, the City of Hudson will be able to produce its own salt brine for use in the drinking water plant's water softening system. This will reduce operating costs for the City and trucking of road salt to the water treatment plant. Additionally, the City will be able use the brine to supplement their salt needs for snow and ice control.

Will the well contaminate the groundwater?
The well will be properly constructed with multiple layers of steel pipe that are cemented to the surface to protect groundwater from the salt brine in the well. Additional protection will be provided by using freshwater drilling fluid, steel tanks, and secondary containment to ensure no contamination occurs.

Will the cavern cause subsidence or a "cave-in"?
When a solution mining well is operated correctly, the roof of the cavern in the salt is protected, and minimal to no subsidence will occur. The City is required to submit an annual survey to Ohio Division of Oil and Gas Resources Management to verify that no subsidence issues are occurring.

How long will a well last?
Depending on many factors such as production rates and how the well is the operated, a well can be expected to have a lifespan of more than 25 years. As an example, Cuyahoga Falls' solution mining well has been in operation since 1967.

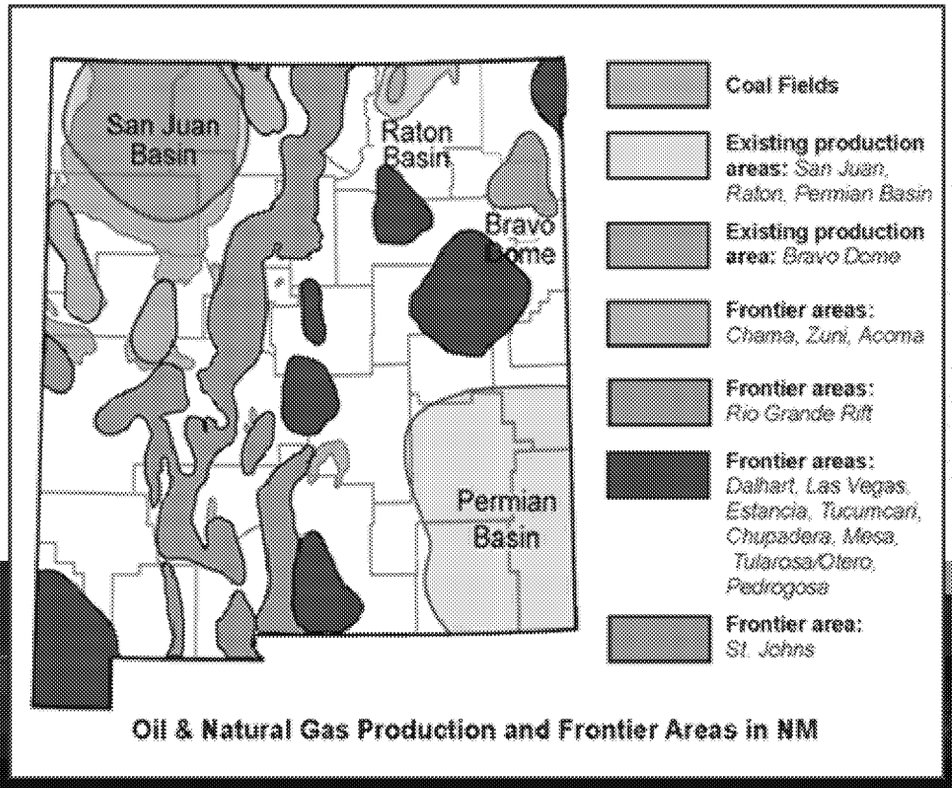
With a salt-solution mining well, the City of Hudson will be able

How does a brine well work?

A salt solution (brine) is produced by injecting treated freshwater through a pipeline down a well, approximately 2,500 feet below the surface, to dissolve the salt beds and create a cavern of saturated brine. The saturated brine is then pumped to the surface and transported through a return pipeline to a storage tank for use. A schematic of the well and piping is shown below.

The Permian Basin located southeast New Mexico and parts of Texas is known for its reserves of crude oil and natural gas. Overlying those the oil and gas reserves are significant layers of salt left behind millions of years ago as an ancient ocean receded.

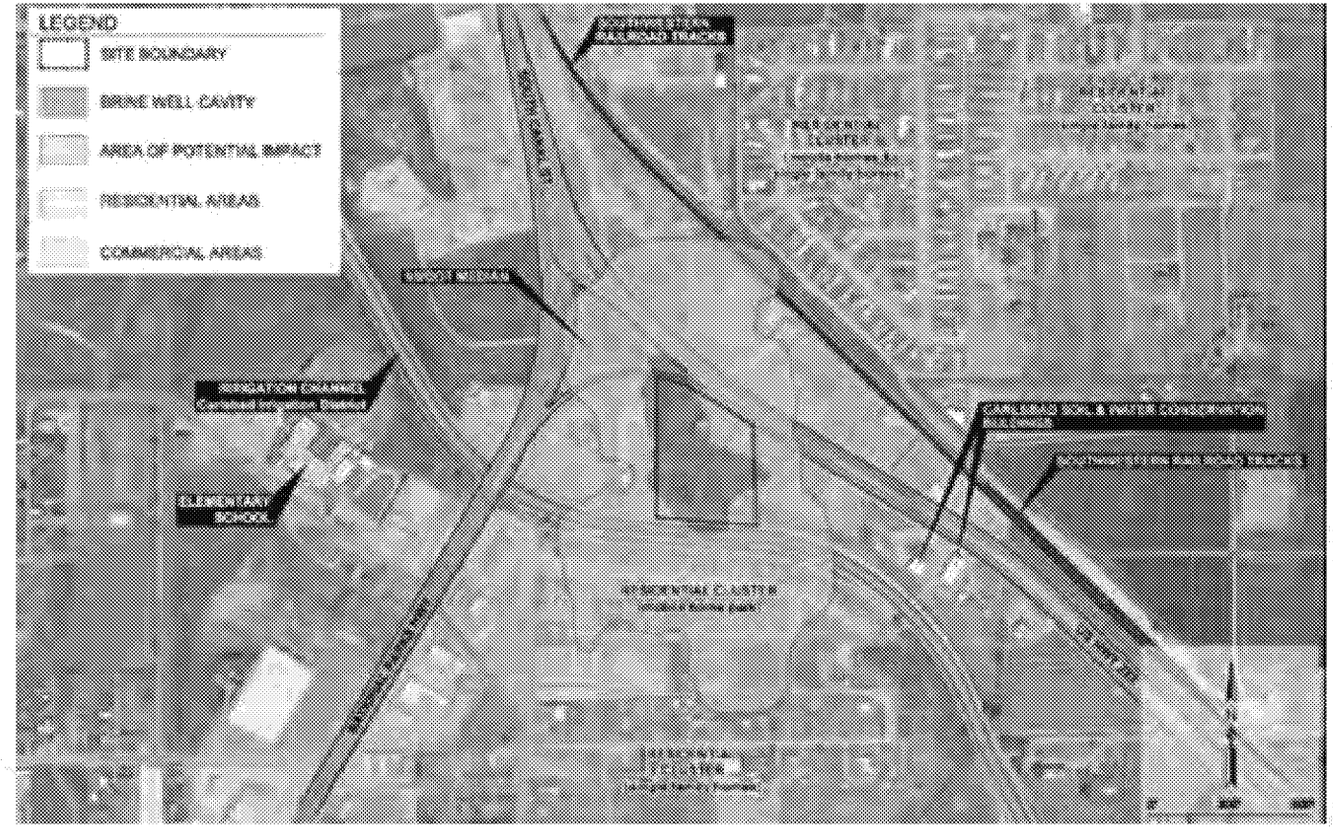
When industry drills through the salt layers to extract the underlying oil and gas, their drilling fluids need to be pre-saturated with salt to ensure the integrity of the boring is not compromised by salt dissolution. A source of brine (salt-laden water) is required. Brine is also used during subsequent workover operations to mitigate existing downhole pressures due to its higher density.



Oil & Natural Gas Production and Frontier Areas in NM

The Carlsbad, New Mexico Brine Well

The Carlsbad Brine Well is located within the Carlsbad city limits, south of the intersection of U.S. Highway 285 (South Canal Street) and 180/62 (National Parks Highway). The Carlsbad Brine Well operated from 1978 to 2008 as a source of brine (salt-laden water) for use in oil well drilling. Fresh water was pumped into the subsurface to dissolve subsurface salt layers, creating a brine that was pumped out and trucked to the oil fields for use in drilling and completions. Removal of the salt created an underground cavity and a risk of collapse of the overlying ground.



The New Mexico Oil Conservation Division (OCD) recognized the hazard in Carlsbad after a brine well southwest of Artesia, NM collapsed in July 2008. A second brine well north of Loco Hills, NM collapsed in November of the same year. It has been estimated that a similar collapse at the Carlsbad Brine Well could cause in excess of $1 billion in damages, affected a main irrigation canal, a major highway intersection, a rail line, and multiple businesses and residences.

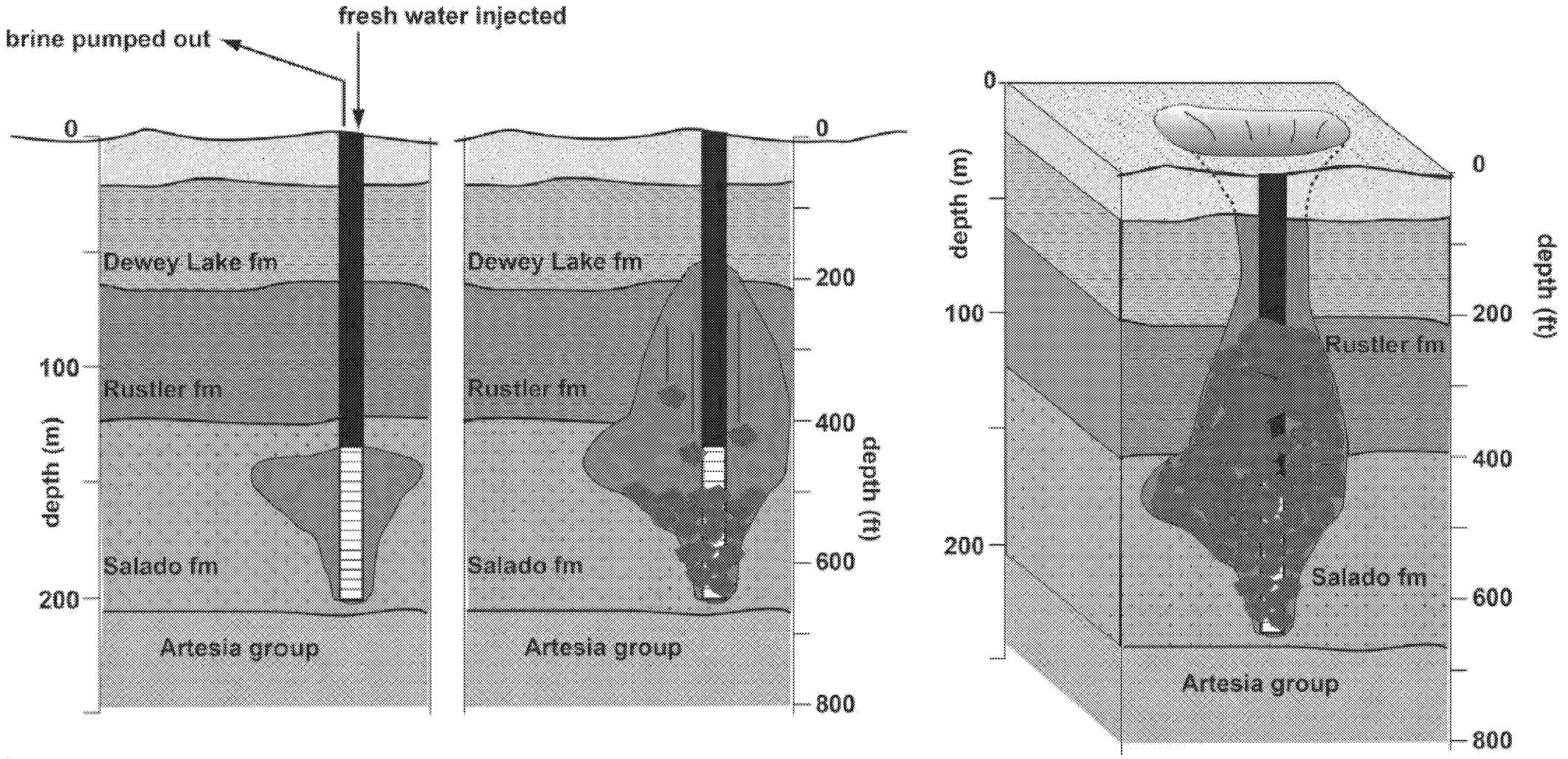
§ 146.4 Criteria for exempted aquifers.

An aquifer or a portion thereof which meets the criteria for an "underground source of drinking water" in § 146.3 may be determined under § 144.7 of this chapter to be an "exempted aquifer" for Class I-V wells if it meets the criteria in paragraphs (a) through (c) of this section. Class VI wells must meet the criteria under paragraph (d) of this section:

(a) It does not currently serve as a source of drinking water; **and**

(b) It cannot now and will not in the future serve as a source of drinking water because:

(4) It is located over a Class III well mining area subject to subsidence or catastrophic collapse;



from Land, L, 2013, *Evaporite Karst in the Permian Basin Region of West Texas and Southeastern New Mexico: The Human Impact,* 13th Sinkhole Conference, National Cave and Karst Research Institute. Symposium 2

§ 146.32 Class III Well Construction requirements

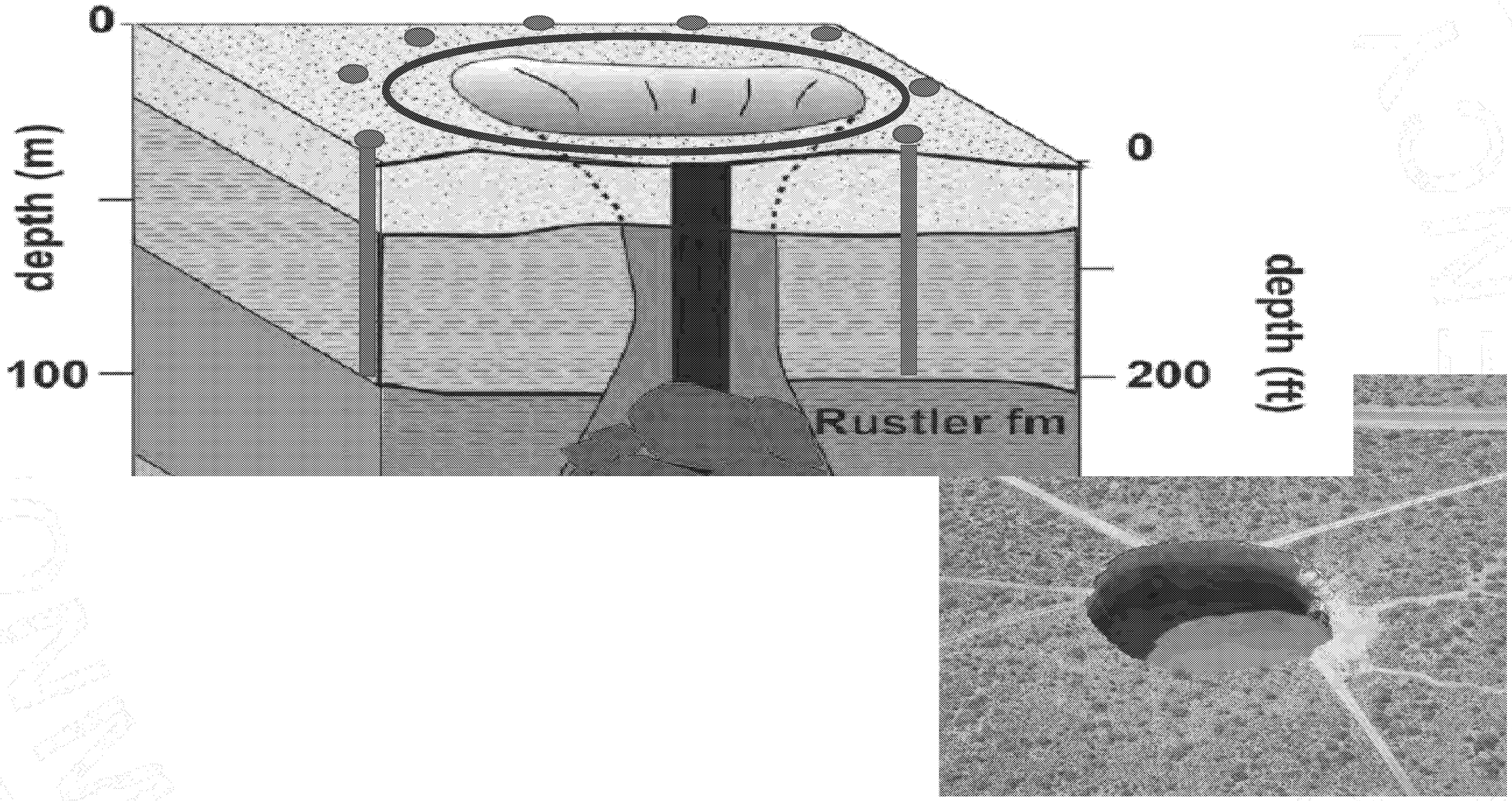
(e) Where injection is into an Underground Source of Drinking Water…

monitoring wells

- In the injection zone and
- In any USDWs above the injection zone which could be affected by the mining operation.

Monitoring well must located in such a fashion as to detect any **excursion of injection fluids**, process by-products, or formation fluids outside the mining area or zone.

(g) If the operation may be affected by **subsidence** or **catastrophic collapse** the monitoring wells shall be located so that they will not be physically affected.


0
depth (m)
100
Rustler fm
0
200
depth (ft)

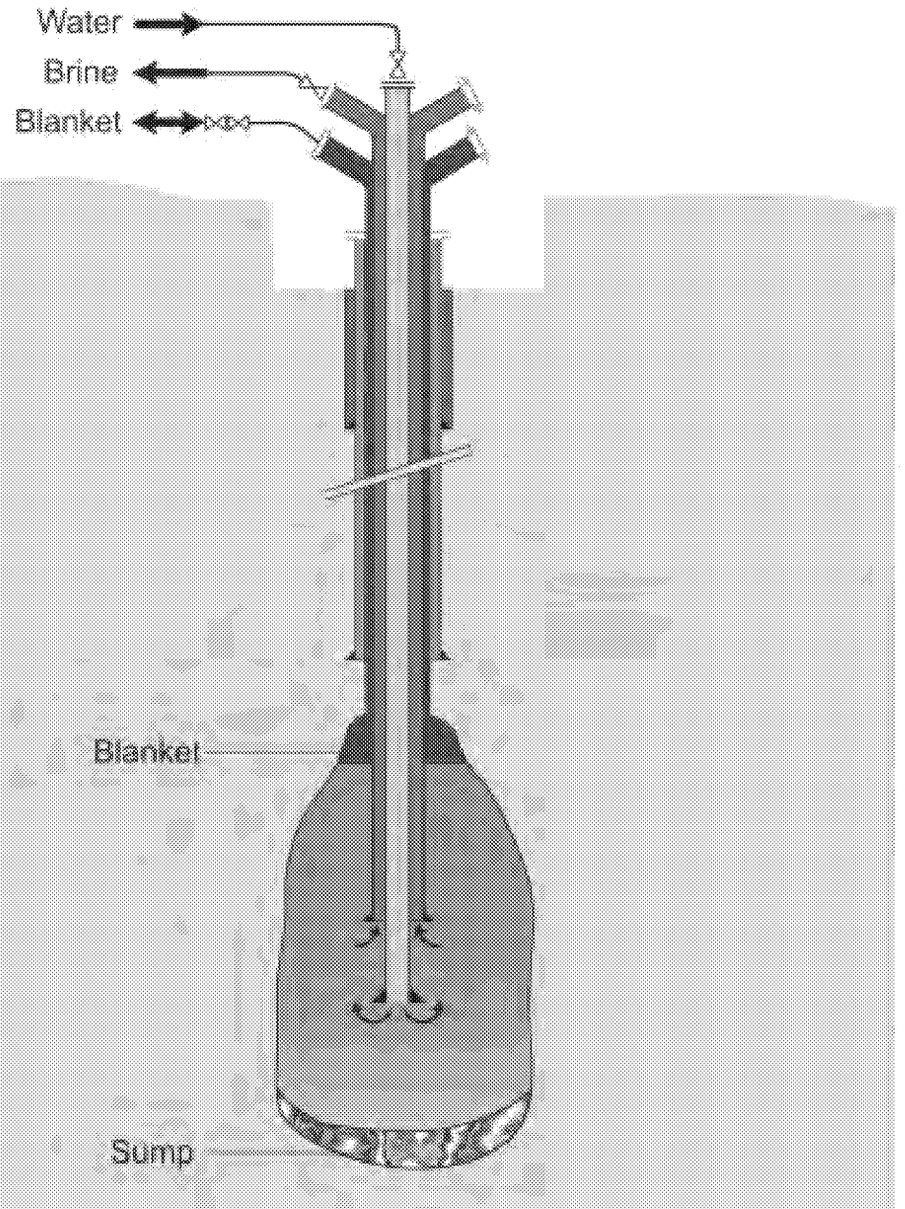
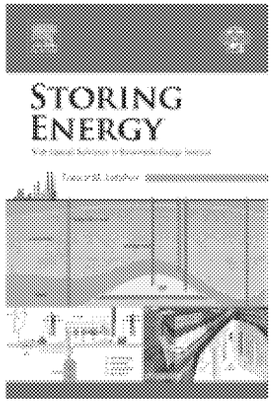


Figure 19.6. Solution mining of a salt cavern. (© KBB Underground Technologieos GmbH.)



Source: Crotogino, Fritz, 2016 Traditional Bulk Energy Storage—Coal and Underground Natural Gas and Oil Storage, in Storing Energy,

End of Presentation